NPS-09-96-010

Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY OF RESEARCH 1995

Department of Oceanography

Robert H. Bourke
Chairman

Edward B. Thornton
Associate Chair for Research

Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral M.J. Evans
Superintendent

R. Elster
Provost

This report was prepared for the Naval Postgraduate School, Monterey, CA.

The report was prepared by:

Frances M. Smith
Research Admin Assistant
Research Office

Reviewed by:

Danielle A. Kuska
Programs Supervisor
Research Office

Released by:

David W. Netzer
Associate Provost and Dean of Research

REPORT DOCUMENTATION PAGE

Form approved

OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1996	Summary Report, 1 January 1995 - 31 December 1995

4. TITLE AND SUBTITLE
Summary of Research 1995, Department of Oceanography

5. FUNDING

6. AUTHOR(S)

Faculty of the Department of Oceanography, Naval Postgraduate School

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

NPS-09-96-010

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words.)

This report contains 43 summaries of research projects in the Department of Oceanography which were carried out under funding of he Naval Postgraduate School Research Program. A list of recent publications is also included which consists of conference resentations and publications, books, contributions to books, published journal papers, and technical reports.

14. SUBJECT TERMS

15. NUMBER OF PAGES
67

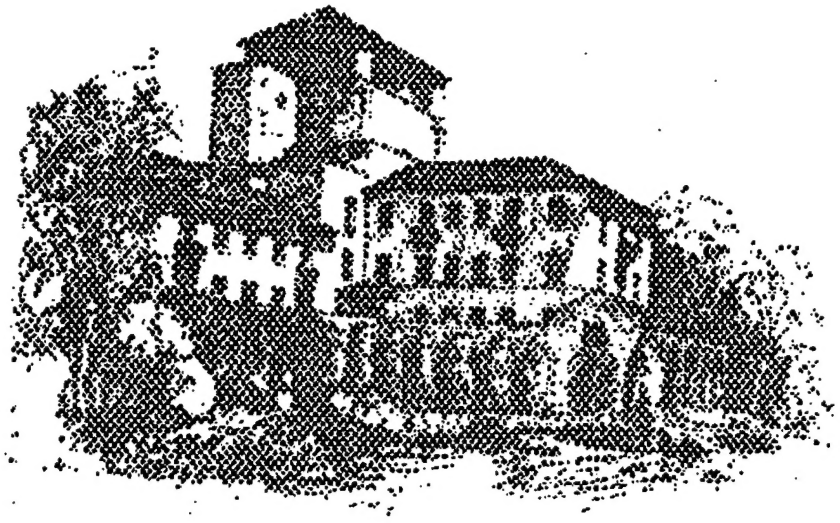
16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Department of Oceanography

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.



Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, managment and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.
- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.
- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).
- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.
- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Oceanography Department is the premier academic center for Naval Oceanography. Our expertise in ocean science is actively sought by both the Naval and civilian community. Military officers from the U.S. and allied nations actively seek admission to our curricula. Faculty participate on panels and committees that influence the future direction of oceanographic research. Our department is recognized internationally for ocean and air-sea interaction modeling and our coastal, nearshore, and polar observational programs are well-established. Such recognition is achieved by high quality, Navy-relevant curricula in physical oceanography and by the high quality of our research. Educational goals include: 1) our graduates must be able to effectively fill all oceanographic assignments that they may encounter during their careers because our educational programs will permit them to confidently use their knowledge to better manage naval operations in the marine environment; and 2) our physical oceanography curricula will be distinguished in the navy relevant areas of air-sea interaction, ocean acoustics, coastal and nearshore processes, numerical modeling and polar oceanography. Students are actively involved from problem definition and data analysis to presentation of results at national meetings and papers published in scholastic journals. The Department of the Navy (DoN) seeks faculty expertise in the furtherance of Naval oceanography and its application to Naval operations.

Table of Contents

OCEANOGRAPHY

Bourke, Robert H.
Professor & Chairman
OC/Bf
408-656-2673 (phone)
408-656-2712 (fax)
bourke@oc.nps.navy.mil

Thornton, Edward B.
Professor & Associate Chair for Research
OC/Tm
656-2847
thornton@oc.nps.navy.mil

Batteen, Mary L.
Associate Professor
OC/Bv
656-3265
batteen@oc.nps.navy.mil

Chui, Ching-Sang
Associate Professor
OC/Ci
656-3239
chiu@oc.nps.navy.mil

Chu, Peter C.
Associate Professor
OC/Cu
656-3688/3257
chu@nps.navy.mil

Clynch, James R.
Research Professor
OC/Cl
656-3268
jclynch@oc.nps.navy.mil

Collins, Curtis
Professor
OC/Co
656-3688
ccollins@nps.navy.mil

Ehret, Laura L.
Research Assistant
OC
656-3440/3685
ehret@oc.nps.navy.mil

Garfield, Newell
Research Assistant Professor
OC/Gf
656-3226
garfield@oc.nps.navy.mil

Garwood, Roland W.
Professor
OC/Gd
656-3260
garwood@nps.navy.mil

Haderlie, E.C.
Professor
OC/Hc
656-2918

Harcourt, Ramsey
Instructor
OC/Ha
656-3624

Herbers, Thomas
Assistant Professor
OC/He
656-2917
herbers@oc.nps.navy.mil

Jiang, Lin
Research Associate
OC/Ji
656-3433
jiang@oc.nps.navy.mil

Ly, Le Ngoc
Research Associate Professor
OC/Le
656-1003
lely@oc.nps.navy.mil

Maslowsksi, Wieslaw
Research Assistant Professor
OC/Ma
656-3162
maslowsk@nps.navy.mil

McClean, Julie
Research Associate Professor
OC/Mn
656-2437
mcclean@oc.nps.navy.mil

Paduan, Jeffrey D.
Assistant Professor
OC/Pd
656-3350
paduan@oc.nps.navy.mil

Paquette, Robert G.
Professor Emeritus
OC/Pa
656-3253
27572P@NAVPGS

Poulain, Pierre-Marie
Assistant Professor
OC/Pn
656-3318
poulain@oc.nps.navy.mil

Rosenfeld, Leslie K.
Research Assistant Professor
OC/Ro
656-3433
role@mabari.org

Semtner, Albert
Professor
OC/Se
656-3267
sbert@oc.nps.navy.mil

Stanton, Tim
Research Associate Professor
OC/St
656-3144
stanton@oc.nps.navy.mil

OCEANOGRAPHY

Wilson, James H.
Adjunct Professor
OC/Wi
656-2690
jhwilson@oc.nps.navy.mil

Zhang, Yuxia
Research Associate
OC/Zh
656-2673
zhangy@ncar.ucar.edu

OCEANOGRAPHY

The Oceanography Department has developed a broad research program focused on physical oceanography to meet the anticipated future needs of the Navy. The priority basic research themes are the development of scientific capabilities to measure, analyze and forecast fields of littoral ocean variables which occur in association with synoptic/mesoscale processes over limited regional and temporal domains. The areas of emphasis include coastal and nearshore ocean dynamics, air-sea interaction phenomena and boundary currents. Regions of interest include the marginal sea ice zone, coastal ocean regions and strategic straits of the world.

The priority applied research themes are the application of analyses and forecasts of upper ocean synoptic/mesoscale variability to Naval operations. Areas of emphasis include the impact of littoral processes, eddies and boundary currents on ocean surveillance systems, the effect of coastal ocean response storms on acoustic propogations and ambient noise and the impact that the wave climate exert on nearshore processes and beach character as pertains to mine/mine countermeasure and amphibious warfare.

These research themes require the development of numerical ocean prediction and synoptic oceanography capabilities. They are achieved through employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-situ and remote sensing observation.

The diverse talents of the faculty of the department are blended by the use of these various techniques to solve problems of common interest. Students are actively involved in these research programs and participate in research cruises, conference presentations and as co-authors of research reports and papers. Much of the research results, both theoretical and applied, are incorporated into the curricula we support. A summarization of particular research areas follows below.

Coastal and Nearshore Oceanography

Professors C.A. Collins, N. Garfield and **Professor Carter** are making regular RAFOS float measurements of the California Undercurrent. The sponsor for these studies is the Office of Naval Research (ONR). **Professors S.R. Ramp, Collins, Garfield** and **L. Rosenfeld** continued analysis of hydrographic and current meter data in the region to the west of the Farallons. These studies were sponsored by the Environmental Protection Agency (EPA) and the Western Division, Naval Engineering Facilities Command. **Professor S.R. Ramp** and **C.A. Collins** continued time series measurements of the current and water mass properties over the continental slope off Pt. Sur to study the long-term seasonal and interannual variability of the flow. **Prof. Ramp** is also investigating the mesoscale variability of weakly nonlinear systems, a five year ONR Accelerated Research Initiative, to study the energy exchanges occurring in eastern boundary currents.

Under sponsorship of ONR, **Professor M.L. Batteen** is using an eddy-resolving, primitive equation coastal model to study the generation, stability, and maintenance of currents and eddies in the California Current System.

Professor J. D. Paduan, with funding from ONR, is using satellite-tracked surface drifters to map the large-scale horizontal surface convergence and eddy statistics in the northeast Atlantic Ocean. He is conducting intensive, single-eddy surveys of features in the California Current System. With support from NPS and ONR, he is undertaking studies of coastal circulation problems in Monterey Bay using high frequency (HF) radar-derived currents as well as drifting buoys, including newly-developed Global Poistioning System (GPS) drifters. Of particular interest are the coastal phenomena of sea breeze-driven currents and topography-generated internal tidal currents. These latter currents and the generation of internal waves in the littoral ocean are being modeled using the three-dimensional, primitive equation Princeton Ocean Model (POM).

Professors E.B. Thornton and T. P. Stanton are developing models to predict the wave-induced three dimensional velocity field and induced sediment transport over arbitrary bathymetry in the nearshore zone, and comparing the models to comprehensive field data. This work is sponsored under three ONR contracts.

Professor Thornton is evaluating wave and current surf zone models and transitioning these to the fleet Tactical Environmental Support System under ONR funding.

Professor T.H.C. Herbers, is investigating the dynamics of ocean surface waves in shallow coastal waters using theory and field observations. Current research projects (funded by ONR) focus on nonlinear wave-wave interactions, shoaling of waves on beaches, the generation of surf beat, and the propagation of waves over a continental shelf.

Professors P.C. Chu and R. H. Bourke, under the sponsorship of ONR, are conducting a study to determine the coherent time and length scales of the temperature and salinity field in the Beaufort Sea using the complete historical hydrographic database for the Beaufort Sea. This research is in support of the field program and modeling effort associated with the Surface Heat Budget of the Arctic Ocean (SHEBA) Experiment.

Acoustical Oceanography

Professors R.H. Bourke and J.H. Wilson are analyzing bottom backscattering data from shallow water areas with a goal of developing a bottom reverberation algorithm for the AN/SQS-53C sonar when operating in shallow coastal waters. They have recently expanded this research to include the new helicopter sonar. Investigations in the past year have centered on quantifying the energy spreading loss phenomenon. The Sponsor is Naval Undersea Warfare Center (NUWC).

Professors R.H. Bourke and J.H. Wilson are developing a predictive ambient noise model for submarines operating in the Arctic Ocean which will forecast periods of extremely loud (>95th percentile level) and quiet (<5th percentile) noise levels. The ANDES noise model has been modified to consider ice generate noise sources and is in the process of being verified. The sponsor is NPS and NUWC.

Professors C.-S. Chiu and A.J. Semtner conducted a simulation study of the variability of low-frequency sound transmission from Hawaii to Monterey using a three-dimensional, ray-based acoustic propagation model and output from the Semtner-Chervin eddy-resolving Parallel Ocean Climate Model. This research, designed to quantify the effects of the inherent ocean variability on detecting the climate signal using acoustic thermometry, was funded by Advanced Research Projects Agency (ARPA) through the SERDP program.

Professors C.-S. Chiu and Robert H. Bourke analyzed the acoustic-tomographic and hydrographic data obtained in the Barents Sea Polar Front Experiment in summer, 1992 for the characterization of the frontal processes and their relation to the observed acoustic variability. The research was funded by ONR.

Professor C.-S. Chiu is preparing for an integrated oceanographic-acoustic field study in the Mid-Atlantic Bight. The research is designed to study the influence of shelf-slope ocean mesoscale processes on the propagation of sound from the continental slope onto the continental shelf. This field study, consisting of a summer and a winter experiment to be conducted jointly with Woodhole Oceanographic Institute (WHOI), is funded by ONR.

Professor C.-S. Chiu convened and chaired the first joint USA-China Conference in Shallow-Water Acoustics at NPS to identify the outstanding basic research topics in shallow-water acoustics which might form the basis of a joint USA-China experiment in the Yellow Sea. The work is funded by ONR.

Professor C.-S. Chiu and the staff of the Coastal Ocean Acoustic Center are continuing the development of the Pt. Sur Ocean Acoustic Observatory. The objectives are to preserve the functionality of the Pt. Sur SOSUS horizontal hydrophone array and to convert the facility into a dual-use Ocean Acoustic Observatory for the purpose of undersea research. The development is sponsored by University of Washington (UW)/Applied Research Laboratory (APL), Center for Monitoring Research (CMR), Monterey Bay Research Institute (MBARI), Naval Postgraduate School (NPS), and Scripps Institute of Oceanography (SIO).

OCEANOGRAPHY

Professors C.-S. Chiu and P. Chu are developing a prototype of a Quick Reaction Littoral Environment Tactical Decision Aid capable of providing interactive littoral environmental information critical to joint warfare operations and analysis. The sponsor is NPS.

Professors K.B. Smith and C.-S. Chiu are investigating time-domain acoustic signal processing and propagation modeling techniques for the localization of sources of acoustic transient signals. The research is funded by NUWC.

Air-Sea Interaction and Ocean Turbulence

Professor T.P. Stanton, participated in the first open ocean iron enrichment experiment under ONR sponsorship by designing a Lagrangian reference frame for the experiment and defining mixed layer processes which contribute to the dispersion of surface injected tracers. Under National Science Foundation (NSF) sponsorship he participated in the Antartic ANZFLUX program by instrumenting the ocean mixed layer to determine the cause of anomalously high winter heat fluxes across the ocean mixed layer in the Weddell Sea. He also participated in the NOAA/ETL COPE experiment to study the contribution of highly nonlinear coastal internal waves to upper ocean mixing.

Prof. R. W. Garwood is sponsored by ONR to simulate the response of Lagrangian drifters, buoys, mines and AUV's to oceanic flows and turbulence in the Labrador Sea. This project is part of a five-year Accelerated Research Initiative (ARI) of ONR to observe and model deep convection in the Labrador Sea.

Ms. Arlene Guest and Professor Garwood have received a three-year grant from NSF for the project "Equatorial Mixed Layer System." This new project is part of the TOGA Coupled Ocean Atmosphere Response Experiment (COARE), to explain large-scale feedback between the ocean and atmosphere in the Western Pacific.

Numerical Prediction and Data Assimilation

Under sponsorship of NSF, **Professor Batteen** is carrying out eddy-resolving, modeling studies of the Leuuwin Current in the coastal region off Western and Southern Australia. Process-oriented studies are being used to explore the roles of thermal and wind forcing, coastline irregularities, and topography in the generation, stability, and maintenance of the currents and eddies in this anomalous eastern boundary current region.

With funding from the National Science Foundation two global 1/4-deg. simulations were made by **Professor Semtner and Ms. Tokmakian** using an improved form of an earlier model and with the best available atmospheric forcing. In addition, satellite altimeter data was used to force the second run, so as to reconstruct the detailed turbulent global circulation of 1992-1995.

Professors Maslowski and Semtner received a grant from Cray Research, Inc. to conduct Arctic Ocean research on massively parallel computers. A very successful 25-year simulation was conducted on a T3D machine in Alaska.

Extensive analyses of model output for the global ocean and regional areas were conducted by **Professors McClean and Semtner** on 1/4- and 1/6-deg. results under sponsorship of the Department of Energy.

A fully coupled model of the Arctic Ocean and its dynamical ice cover was constructed through guidance of the joint NOAA research of **Professor Maslowski and Dr. Zhang**. Simulations with atmospheric forcing of 1990-94 were begun.

Under the sponsorship of ONR, **Prof. P.C. Chu** is developing a three dimensional diagnostic/prognostic system for the South China Sea. This research is contributing to a recently initiated International South China Sea Monsoon Experiment. He is also sponsored by NPS and ONR to develop a new diagnostic system (P-vector method) for computing 3-D ocean circulation from hydrographic data.

OCEANOGRAPHY

Marine Operations

Mr. B. Miller and **Professor R.H. Bourke** managed shipboard support for NPS at-sea instruction and research projects off the central California coast. Fifty-one days of operations were carried out on the Research Vessel (R/V) Pt. Sur. Students and faculty participated in these shipboard projects from both the Departments of Oceanography and Meteorology. The sponsor for this project is the Commander, Naval Oceanography Command. NPS acquired the Point Sur SOSUS array and it is being used in a variety of reimbusably-funded research projects.

Professor J. R. Clynch, with funding from Naval Command, Control and Ocean Surveillance Center, In-Service Engineering (NISE-West), conducted studies to improve the aircraft landing system in Antarctica using GPS and also evaluated the merging of GPS data with the TACAN system. Dr. Clynch is also investigating how the Defense Mapping Agency can make use of available DoD GPS receivers in their applications.

OCEANOGRAPHY

Meteorology and Oceanography Sciences Laboratories

NPS has an active seagoing research program in oceanography, meteorology, and environmental acoustics. Instrumentation aboard the R/V POINT SUR includes CTD (conductivity, temperature, depth) and expendable bathythermograph (XBT) systems, an acoustic Doppler velocity profiler (ADVP), an acoustic (atmospheric) sounder, a micrometeorologically instrumented mast, continuous underway measurements of conductivity and temperature at 2 m, position, (including Global Positioning System and Loran receivers) and surface atmospheric variables, and a contemporary digital data-acquisition system. The Oceanography Department maintains a suite of modern current-measuring equipment for experimental use including Aanderaa current meters and electromagnetic current meters, acoustic Doppler profilers, and acoustic releases; drifting buoys of various types are also available. The micrometeorological instrumentation suites are used on aircraft and abroad ship. Other facilities include analysis laboratories for mesoscale ocean prediction, ocean turbulence, nearshore processes, satellite remote sensing, and numerical meteorology and oceanography. Access is also provided to supercomputer facilities at NCAR, the Naval Research Laboratory, and the Naval Oceanographic Office. Synoptic laboratory facilities include access to both National Meteorological Center (NMC) and Fleet Numerical Meteorology and Oceanography Center (FNMOC) numerical analysis and prognoses, real-time satellite data, and surface and upper-air observation capability. Acoustic transceivers, a listening array off Point Sur, and associated analysis facilities are also available.

The Meteorology Department's new Marine Atmospheric Measurements Laboratory features state-of-the-art instrumentation for calibration work and for probing the atmosphere with both in situ and remote-sensing devices. The laboratory features meteorological ground stations, 405 and 915 MHZ doppler-radar wind profilers, a rawinsonde system, a SODAR system, and a fully instrumented surface weather station. A major center for interdisciplinary remotely piloted aircraft studies (CIRPAS) is currently being established with two field programs planned for 1996. An Interactive Digital Environmental Analysis Laboratory (IDEA Lab) provides modern computer technology and real-time data bases for graduate instruction and research in synoptic oceanography and meteorology, remote-sensing applications, and numerical weather prediction. The IDEA Lab consists of 16 UNIX workstations that support numerical computation, graphics, image analysis, and visualization. Real-time local data from the Measurements Laboratory; global data acquired through UNIDATA, DMSP, and GOES satellite data; and analysis and forecast products from NMC, FNOC, and ECMWF are available for analysis and display in a modern Synoptic Laboratory with large-screen video/animation capability.

FY95 REIMBURSABLE PROGRAM
Department of Oceanography

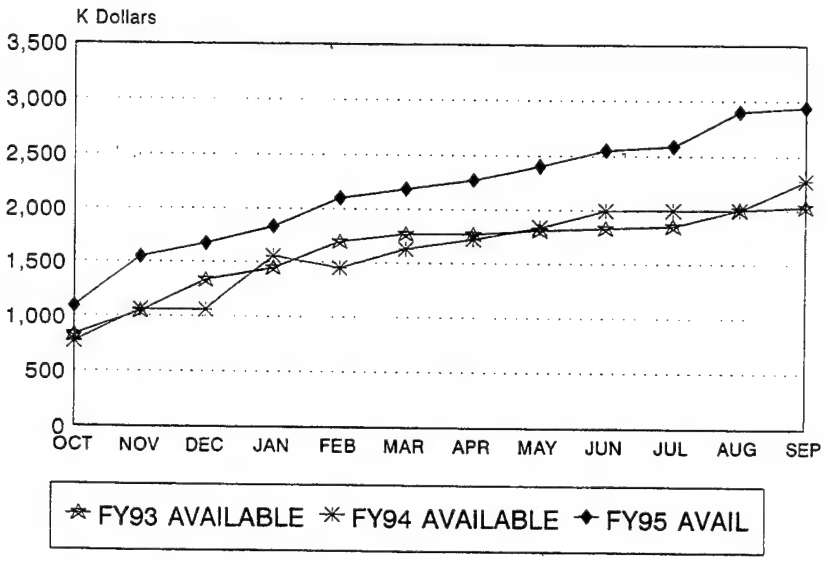


Figure 1. Reimbursable Funds Available by Fiscal Year.
This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities.

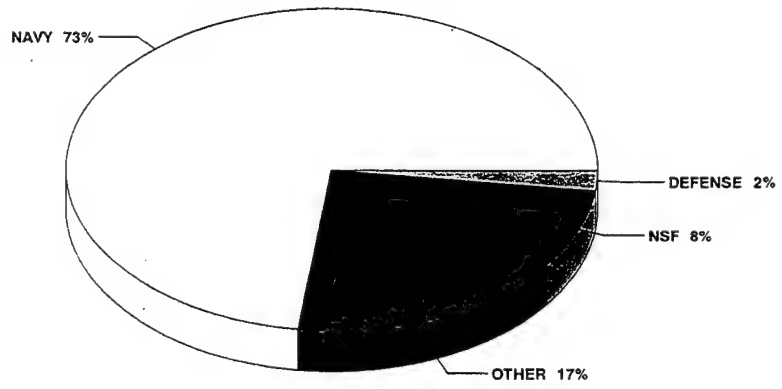


Figure 2. FY95 Reimbursable Sponsor Profile.

EDDY-RESOLVING MODELING STUDIES OF THE LEEUWIN CURRENT

Mary L. Batteen, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The overall goals of this research are to carry out process-oriented modeling studies to investigate the generation and stability of currents and eddies in the anomalous Leeuwin Current region, and to better describe the contributing forcing mechanisms, and their relative importance. To carry out these goals, it was proposed to extend the eddy-resolving, process-oriented modeling studies by adding the following features to the model: 1) wind forcing, 2) extension of the model domain to include the Southern Australia coastal region, and 3) bottom topography. This work is part of a continuing project which began in 1992 and ends in 1996.

SUMMARY: Idealized wind forcing has been added, representative of the period of maximum Leeuwin Current flow (austral autumn/austral winter), and the model domain has been extended (which was a closed eastern boundary with open borders to the north, west, and south) to include the Southern Australian region. Both an idealized and an irregular coastline were also incorporated into the model.

The results demonstrate the respective roles that thermal forcing, wind forcing, and coastline geometry play in the Leeuwin Current System. The results show that:

1) Although thermal forcing is the dominant forcing mechanism in the Leeuwin Current System and gives rise to the Leeuwin Current and undercurrent, the winds along the irregular coastline act to increase the current baroclinicity via upwelling along the west coast, and produce an intensified current along with a strong temperature front along the south coast. The winds oppose the thermal forcing along the west coast, which effectively decreases the magnitude of the poleward current (and undercurrent). Near Cape Leeuwin, easterly winds enhance the current flow around the cape;

2) the North West Shelf (NWS) water dominates the source region which effectively eliminates regional upwelling; the NWS water contributes to warmer waters advected into the Great Australian Bight and regenerates coastal measoscale features near the source region. With time the wind forcing effects increase and act to recede the NWS water back towards the source region;

3) Instability mechanisms show that baroclinic (barotropic) instability processes dominate the west (south) coast;

4) Eddies propagating westward result in a division of the onshore geostrophic flow. An offshore poleward and a narrow inshore poleward flow reunite at Cape Leeuwin further increasing regional horizontal and vertical shears, which lead to a semi-permanent feature in the vicnity of Cape Leeuwin.

The results are consistent with avalable observations of the Leeuwin Current from satellite, current meter, and drifting buoy data.

PUBLICATION:

Batteen, M.L. and Braccio, P.G., "Modeling Studies of Eastern Boundary Coastal Circulations: A Comparison of the California and Leeuwin Current Systems," XXI International Association for the Physical Sciences of the Oceans (IAPSO) Abstracts, PS-04.508, p. 9, 1995.

CONFERENCE PRESENTATION:

Batteen, M.L., and Braccio, P.G., "Modeling Studies of Eastern Boundary Coastal Circulations: A Comparison of the California and Leeuwin Current Systems," XXI International Association for the Physical Sciences of the Oceans, Honolulu, HI, August 1995.

THESIS DIRECTED:

Butler, C.L., "Modeling Studies of the Leeuwin Current off Western and Southern Australia," Master's Thesis, December 1994.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal oceanograohy, ocean modeling, ocean circulation

COASTAL MODELING STUDIES OF EASTERN BOUNDARY CURRENTS

Mary L. Batteen, Associate Professor
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The scientific goal of this research is to use a high-resolution, multi-level, primitive equation, regional ocean model to systematically investigate current and eddy structures in eastern boundary current (EBC) regions. The studies should provide improved physical understanding of EBCs.

SUMMARY: A high-resolution, primitive equation ocean model has been used to isolate the response of the Chile Current System to equatorward and seasonal wind forcing, and of the California Current System to seasonal wind forcing. In both systems, an equatorward surface current, a poleward undercurrent, upwelling, filaments, meanders and eddies were simulated. A mixed (baroclinic/barotropic) process was shown to be responsible for the generation of the meanders and eddies. The results from these experiments support the hypothesis that wind forcing is an important forcing mechanism for the generation of many of the observed features of EBCs.

PUBLICATIONS:

Batteen, M.L., Hu, C.-P, Bacon, J.L., and Nelson, C.S., "A Numerical Study of the Effects of Wind Forcing on the Chile Current System," Journal of Oceanography, Vol. 51, pp. 585-614, 1995.

Batteen, M.L., Collins, C.A., Gunderson, C.R., and Nelson, C.S., "The Effect of Salinity on Density in the California Current System," Journal of Geophysical Research-Oceans, Vol. 100, No. C5, pp. 8733-8749, 1995.

Batteen, M.L.. "Process-Oriented Modeling Studies of Wind Forcing Effects on the California Current System," Research Activities in Atmospheric and Oceanic Modeling, A. Staniforth (editor), CAS/JSC Working Group on Numerical Experimentation, Vol. 21, 8.7, 1995.

Batteen, M.L., and Braccio, P.G., "Wind-Forced Modeling Studies of the California Current System," Abstracts from the Eastern Pacific Ocean Conference, p.6, 1995.

CONFERENCE PRESENTATION:

Batteen, M.L., and Braccio, P.G., "Wind-Forced Modeling Studies of the California Current System," Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf, CA, September 1995.

OTHER:

Batteen, M.L., "Wind-Forced Modeling Studies of Currents, Meanders, and Eddies in the California Current System," submitted to Journal of Geophysical Research-Oceans.

OCEANOGRAPHY

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal oceanography, ocean modeling, ocean circulation

GLOBAL ACOUSTIC PATH VARIABILITY STUDY

Ching-Sang Chiu, Associate Professor
Albert J. Semtner, Professor
Department of Oceanography
Sponsor: University of California, San Diego

OBJECTIVE: The objective of this project is to quantify the inherent variability of the cross-basin acoustic transmissions as planned by the Acoustic Thermometry of Ocean Climate (ATOC) Project using numerical models.

SUMMARY: The influence of mesoscale, gyrescale and seasonal ocean variability on three-dimensional (3D) acoustic raypaths from the planned Hawaii to Monterey site was modeled. Ray paths and signal arrival structure over a two year period were simulated at a six-day interval using a 3D ray-based acoustic model. The input sound speed fields were interpolated from gridded (1/4 degree, 20 level) temperature and salinity output data from the Semtner-Chervin eddy-resolving Parallel Ocean Climate Model (POCM). Based on the simulated acoustic multipath arrival structure, the issues of stability and travel time variability were addressed. Arrival structure was found to be strongly dependent on receiver depth and quasi-stable over time with a 0.6 correlation between arrival patterns at different times. Travel time variability estimates were 0.42 s rms for steep rays, due to a combination of seasonal and mesoscale ocean variability, and 0.28 s rms for near-axial rays, due primarily to seasonal variability.

PUBLICATION:

Staten, R.A., Chiu, C.-S., and Semtner, A.J., "A Simulation Study of the Variability of Acoustic Transmissions from Hawaii to Monterey," Proceedings of the 2nd International Conference on Theoretical and Computational Acoustics (D. Lee et al. editors), World Scientific, 1995, in press.

CONFERENCE PRESENTATION:

Staten, R.A. and Chiu, C.-S., "A Simulation Study of the Variability of Acoustic Transmissions from Hawaii to Monterey," 2nd International Conference on Theoretical and Computational Acoustics, Honolulu, HI, 21-25 August 1995.

THESIS DIRECTED:

Staten, R.A., "A Simulation Study of the Variability of Acoustic Transmissions from Hawaii to Monterey," Master's Thesis, September 1995.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Acoustics, modeling, climate, variability

OCEANOGRAPHY

BARENTS SEA DATA ANALYSIS

Ching-Sang Chiu, Associate Professor
Robert H. Bourke, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Using hydrographic and acoustic data collected in a 1992 experiment over the steep northwestern slope of the Bear Island Trough and numerical ocean and acoustic models, the objectives of the project are: 1) to characterize the dynamics of the Barents Sea Polar Front (BSPF) which is the dominant mesoscale feature in the Barents Sea, 2) to examine the relationship of BSPF to the regional oceanography, and, 3) to quantify the variability of the acoustic wavefield in relation to the frontal oscillations.

SUMMARY: Co-advised by R.H. Bourke and A.J. Semtner, the relation of BSPF to the regional oceanography was examined by A.R. Parson in his Ph.D. thesis. A high resolution (1/6 degree and 30 vertical levels) Arctic Ocean and Nordic Sea model was developed from the Semtner-Chervin General Circulation Model (GCM) with a free surface. Three numerical experiments, with annual mean forcing, annual mean forcing coupled with semidiurnal tidal forcing and seasonal forcing, respectively, were conducted to simulate conditions in 1992. Significant changes in the temperature, salinity and current structure due to tidal mixing were seen throughout the Barents Sea when compared to simulations without tides. The predicted mean transport into the Barents Sea was reduced by 0.4 Sv as a result of the tidally induced residual flow. This reduced transport was in closer agreement with estimates based on observations. Modeling predictions also indicate that the coherent advection of the Barents Polar Water (BPW) to the front summertime is contingent upon strong surface stratification of the upper layers from the summer ice melt.

The variability of acoustic pulse transmissions cross front was studied using a model-based, minimum-mean-square-error ray/mode former of the vertical array data. Using predictions by state-of-the-art range-dependent ray and mode shallow-water propagation models and estimated statistics of pulse distortion and translation as additional constraints, this newly developed filtering method significantly improved the resolution of individual ray and mode arrivals with sidelobes minimized. The magnitude and time fluctuations displayed in the time series of the ray and mode arrivals were extracted and analyzed. These fluctuations were induced by frontal movements, tidal oscillations and internal waves, with different rays and modes affected differently. The acoustic results were reported in several publications by Chiu et al., Lynch et al. and Gin et al., respectively.

PUBLICATIONS:

Chiu, C.-S., Miller, J.H., and Lynch, J.F., "Forward Coupled-mode Propagation Modeling for Coastal Acoustic Tomography," Journal of Acoustical Society America, 1995, in press.

Chiu, C.-S., Miller, J.H., and Denner, W.W., "Modeling of Backscatter and Barrier Sonar System Concepts using a Coupled Normal-Mode Approach (U)," Journal of Underwater Acoustics, pp. 103-116, 1995.

Lynch, J.F., Jin, G., Pawlowicz, R., Ray, D., Chiu, C.-S., Miller, J.H., Bourke, R.H., Parsons, A.R., Plueddemann, A.J., and Muench, R., "Acoustic Travel Time Perturbations due to Shallow Water Internal Waves and Internal Tides in the Barents Sea Polar Front: Theory and Experiment," Journal of Acoustical Society America, 1995, in press.

Parsons, A.R., Bourke, R.H., Muench, R., Chiu, C.-S. Lynch, J.F., Miller, J.H., Plueddemann, A.J., and Pawlowicz, R., "The Barents Sea Polar Front in Summer," accepted Journal Geophysical Research.

Jin, G., Lynch, J.F., Chiu, C.-S. and Miller, J.H., "A Simulation Study of Acoustic Normal Mode Coupling Effects due to the Barents Sea Polar Front, with Applications to Acoustic Tomography and Matched Field Processing," accepted Journal Acoustical Society America.

Chiu, C.-S., Miller, J.H., Denner, W.W., and Lynch, J.F., "A Three-Dimensional, Broadband, Coupled Normal-Mode Sound Propagation Modeling Approach," Full Field Inversion Methods in Ocean and Seismic Acoustics (O. Diachok, A. Caiti, P. Gerstoft and H. Schmidt editors), Kluwer Academic Publishers, pp. 57-62, 1995.

Chiu, C.-S., Miller, J.H., Denner, W.W., and Lynch, J.F., "Forward Modeling of the Barents Sea Tomography Vertical Line Array Data and Inversion Highlights," Full Field Inversion Methods in Ocean and Seismic Acoustics (O. Diachok, A. Caiti, P. Gerstoft and H. Schmidt editors), Kluwer Academic Publishers, pp. 237-242, 1995 (Invited Paper).

CONFERENCE PRESENTATION:

Lynch, J.F., Jin, G., Traykovski, P., Chiu, C.-S, and Miller, J.H., "Scattering of Acoustic Tomographic Signals in Shallow Water by Internal Waves," 129th Meeting of the Acoustical Society of America, Washington, DC, 30 May - 3 June 1995.

THESIS DIRECTED:

Parsons, A.R., "On the Barents Sea Polar Front in Summer and Interpretations of the Associated Regional Oceanography using an Arctic Ocean General Circulation Model," Ph.D. Dissertation, September 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Frontal dynamics, shallow-water acoustics, coastal tomography

MIDDLE ATLANTIC BIGHT FIELD STUDY

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: In collaboration with Woods Hole Oceanographic Institution and Harvard University, the objectives of this multi-year, multi-institutional field study in the Middle Atlantic Bight are: 1) to obtain a high resolution description of the spatial and temporal evolution of the shelf-break front, and to clarify the mechanisms by which eddies are formed and detached; 2) to determine the mean and seasonally varying circulation of the adjacent slope water, and characterize the mesoscale fluctuations in relation to shelf-break processes; 3) to determine the effects of basic mean shelf-break frontal thermal structure on the propagation of sound from the continental slope to the continental shelf; 4) to relate the temporal and spatial variability of acoustic propagation from the continental slope to the continental shelf with the associated variability of the shelf-break front; and, 5) to make fully three-dimensional tomographic images of the region of the shelf-break front for use in the physical oceanographic studies.

SUMMARY: The measurement program of this study includes two intensive three-week experiments, one in July 1996 and the other one in February 1997. Specifically, each of the two experiments will employ a suite of new observational techniques. These include SeaSoar, remote sensing and an acoustic tomography array consisting of three transceivers and two vertical hydrophone arrays straddling the shelf-break front. The Naval Postgraduate School is participating in all phases of the study including experimental planning, data collection, data processing, acoustic modeling, and data analysis. In 1995, three acoustic transceivers, six current meters, one ADCP, and four acoustic releases were prepared for the first field deployment. Acoustic models were run to determine an optimal configuration for the tomography array. Important design parameters including source depths, ranges, etc., were derived and optimal mode filtering techniques investigated.

CONFERENCE PRESENTATION:

Chiu, C.-S., "Simulation Results of Acoustic Mode Propagation and Filtering Pertaining to PRIMER Tomography," 1st PRIMER Workshop, Woods Hole, 17 October, 1995.

THESIS DIRECTED:

Kaemmerer, G.-E., "Simulation of Acoustic Multipath Arrival Structure in the Middle Atlantic Bight," Master's Thesis, June 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Frontal dynamics, shallow-water acoustics, coastal tomography

USA-CHINA CONFERENCE ON SHALLOW WATER ACOUSTICS

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of the conference is to identify the outstanding basic research topics in shallow-water acoustics which might form the basis of a joint USA-China experiment in the Yellow Sea.

SUMMARY: Sponsored by the ONR Underwater Acoustics Program and hosted by the Superintendent of NPS, the Principal Investigator convened and chaired a three-day Joint USA-China Conference on Shallow-Water Acoustics in December, 1995 at NPS. The attendees included the top-notch acoustical oceanographers and underwater acousticians from the two countries (nine Chinese and twelve Americans). Several outstanding research topics in coastal ocean acoustics which are of common interest to both countries, such as the effects of internal waves and sediment structure on sound transmission, were identified and discussed. The scientific approaches, logistic issues, available technology, environmental conditions and sites for a potential collaborative experiment in the Yellow Sea to study the topics identified were also discussed and assessed. A plan of action was recommended.

DOD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Shallow-water acoustics

DEVELOPMENT OF THE POINT SUR OCEAN ACOUSTIC OBSERVATORY

Ching-Sang Chiu, Associate Professor
Department of Oceanography
Sponsors: Applied Physics Laboratory, UW, Center for Monitoring Research, Monterey Bay Aquarium Research Institute, Naval Postgraduate School, and Scripps Institute of Oceanography

OBJECTIVE: The objectives are: 1) to preserve the functionality of the Point Sur SOSUS horizontal hydrophone array; and, 2) to convert the facility into a dual-use Ocean Acoustic Observatory for the purpose of undersea research.

SUMMARY: In 1995, the Point Sur Ocean Acoustic Observatory in the Monterey Bay National Marine Sanctuary was established, for the purpose of undersea research. The five sponsoring organizations contributed greatly to this commendable community effort. Their contributions were in terms of hardware, reimbursable funding for electric and electronic maintenance, labor, and the conduct of high-quality research using the data. In particular, the 1995 effort

entailed a major repair of the concrete protection cap for the SOSUS array cable, where it adjoins the bluff. The cap was thoroughly repaired in fall of 1995 and the unclassified data were actively used by the civilian community for nuclear test ban treaty monitoring, ocean circulation studies, and marine mammal studies.

DOD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Coastal acoustics, SOSUS, dual-use

QUICK REACTION LITTORAL ENVIRONMENT TACTICAL DECISION AID

Ching-Sang Chiu, Associate Professor
Peter Chu, Associate Professor
Department of Oceanography
Sponsor: Naval Postgraduate School - Institute of Joint Warfare Analysis

OBJECTIVE: The goal of this research is to develop a prototype of an automated, high-resolution, coupled air-ocean modeling system capable of providing interactive littoral environmental information critical to joint warfare operations and analysis.

SUMMARY: Accomplishments in 1995 include: 1) the system paradigm of the Quick Reaction Littoral Environment Tactical Decision Aid (QLTDA) was conceptualized and various modules of QLTDA and their interconnections were defined; 2) collected the available data important for the development of the capability to derive optimal analyzed ocean fields was collected; 3) the Navy's Shallow Water Analysis and Forecast System (SWAFS), a modeling system with fully active thermodynamics and mixed layer physics for imposing dynamical constraints on the derivation of analyzed fields to relate data measured at different locations and times was adapted; and, 4) the data management and visualization packages originated from Naval Oceanographic Office and the Center for Air Sea Technology (CAST) of the Mississippi State University was adapted. The adapted packages provide an interactive, graphical user environment for editing and analyzing oceanographic sounding (bathythermograph, conductivity-temperature-salinity and sound speed) profile data as well as gridded data.

DOD KEY TECHNOLOGY AREAS: Human-Systems Interfaces, Modeling and Simulation, Battlespace Environments, Computing and Software

KEYWORDS: Littoral, virtual, environment, air-ocean, interactive

P-VECTOR METHOD FOR DETERMINING OCEAN CIRCULATION FROM HYDROGRAPHIC DATA

Peter C. Chu, Associate Professor
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal is to obtain a description of the large-scale circulation in the oceans. Determination of the general circulation is an important step toward understanding global climate, the distribution of chemical properties in the ocean, and the other problems. The dynamics of large-scale circulation features such as the meandering, the gyres, and the recirculation of the Gulf stream is the focus of the research project. The purpose of the research is to seek an in-depth understanding of the dynamics and the ramifications of these features. With this support, the principal investigator has obtained reimbursable funding from the Office of Naval Research.

SUMMARY: Most knowledge of the general circulation of the world oceans is based on the classical dynamical method. Under the assumption of geostrophic balance, one computes the vertical shear of velocity from observed hydrographic data. The major difficulty with this method is that there is missing constant of integration. This missing constant, the barotropic velocity, cannot normally be determined by direct means. The current inverse methods developed based on the geostrophic balance and mass conservation don't check the two ill-conditions: 1) no intersection between the isopycnal surface and the potential vorticity surface, and, 2) no beta-spiral turning. A new thrust is the effort to formulate the inverse problem for the calculation of absolute velocity from the T-S data with the ill-condition check-up.

A new inverse method (the P-vector method) with ill-condition check-up and error estimation has been developed to compute the North Atlantic ocean circulation from the climatological T-S data. Realistic ocean circulations were obtained using the P-vector method, which does not incorporate turbulent mixing, and the beta-spiral method, which does use turbulent mixing (Olbers et al. 1985). Both use the same climatological data (Levitus, 1982). This indicates that the main features of ocean general circulation is determined by the density field. The P-vector method leads to a better initialization scheme for ocean numerical models.

PUBLICATIONS:

Chu, P.C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," Journal of the Marine Technology Society, Vol. 29, No. 2, pp. 3-14, 1995.

Chu, P.C., "S-transform for Obtaining Localized Spectrum," Journal of Marine Technology Society, Vol. 29, in press.

CONFERENCE PRESENTATIONS:

Chu, P.C., and Lozano, C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Lozano, C. and Fan, C.W., "A Regularized Inverse for Beta-spiral Dynamics," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Lozano, C., and Chu, P.C., "Ocean Circulation Analysis with Three Conserved Variables," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Fan, C.W., and Lozano, C.J., "P-vector Method for Assimilating Hydrographic Data into Ocean Circulation Models," American Geophysical Union Fall Meeting, San Francisco, CA, 12-16 December 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: P-vector, geostropic velocity, beta-spiral, inverse method

LITTORAL ZONE PREDICTION SYSTEM

Peter C. Chu, Associate Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVE: This is a joint research project with the Naval Oceanographic Office (NAVOCEANO) to improve the littoral zone naval ocean prediction systems by: 1) studying the relationship between the sea surface temperature (SST) and the subsurface ocean thermal structure, and, 2) investigating the horizontal coherence length scale in selected

coastal regions and their dependence on random oceanographic/meteorological events. The regions for the study will be selected depending on the Navy's interest. This research project is closely related to the new curricula the principal investigator is developing (OC4335, Naval Ocean Analysis & Prediction), and will be several thesis research projects (co-advised by Drs. M. Carron and S. Haeger at NAVOCEANO).

SUMMARY: Under the guidance of the Oceanographer of the Navy Office (CNO-N096) and Commander, Naval Meteorology and Oceanography Command (CNMOC), and with the support from NAVOCEANO, an integrated education and research program, Naval Ocean Analysis and prediction (NOAP), was recently established at the Oceanography Department at NPS. NOAP provides a unique blend of education, research, and service to support Operational Meteorology and Oceanography (METOC) mission objectives. The on-going Joint NAVOCEANO-NPS research project is a major part of this program.

Over the last several years, there has been a rapid refocusing of the Navy's resources to support joint warfare. Specifically, NAVOCEANO, NRL, and NPS are implementing ocean modeling systems in several ocean basins; these systems include not only the models per se, but historical and real-time data. Historical data set is required to understand the basic physics in order to properly optimize a model to a specific basin. Real-time data is required for assimilation by a model when running an operational mode. In addition to ocean modeling, NAVOCEANO also performs direct analysis on data to construct products in the Warfare Support Center (WSC). Several types of analyses of historical environmental data are requited to both optimize our modeling efforts in specific basins, as well as to provide synthesized information for other WSC products. These analyses include the use of data such as historical wind observations, FNMOC modeled wind fields, subsurface current meters, Master Oceanographic Observations Data Set (MOODS) profiles, and recent AXBT surveys by NAVOCEANO. Several new techniques were presented in the international conferences and will be published in relevant journals.

PUBLICATIONS:

Chu, P.C., Fralick, C.R., Haeger, S.D., and Carron, M.J., "A Thermal Parametric Model for the Continental Shelf," Journal of Marine Systems, in revision.

Chu, P.C., Wells, S.K., Haeger, S.D., Szczechowski, C., and Carron, M.J., "Temporal and Spatial Scales of the Yellow Sea Thermal Variability," Journal of Marine Systems, in revision.

CONFERENCE PRESENTATIONS:

Chu, P.C., Wells, S., Haeger, S., Szczechowski, C., and Carron, M., "Spatial and Temporal Decorrelation Scales of the Yellow Sea Thermal Fields," International Liege Colloquium on Dynamics of the Regions of Fresh Water Influence, Liege, Belgium, 8-13 May 1995.

Chu, P.C., Fralick, C., Haeger, S., and Carron, M., "A Feature Model for the Continental Shelf Thermal Structure," International Liege Colloquium on Dynamics of the Regions of Fresh Water Influence, Liege, Belgium, 8-13 May 1995.

OTHER:

The results from the MOODS data analysis have been used by the Operations Directorate (N3T) of the Naval Oceanographic Office. The determination of open boundary conditions by the P-vector method will be used by Modeling and Techniques Department of the Naval Oceanographic Office.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean prediction, littoral zone

OCEANOGRAPHY

CIRCULATION AND DIFFUSION STUDIES OF THE SOUTH CHINA SEA

Peter C. Chu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of the project is to understand the physical processes of the South China Sea and to establish a nowcast/forecast system for regional seas, including the South China Sea. The model will have the capability of diagnosing 3-D current velocity and T-S fields from satellite and sparse in-situ observations. The nowcast system will be user friendly, easily embedded into the prediction system (e.g., the Navy's SWAFS), and ready to transition to the operational use. The combined nowcast/forecast system will greatly enhance the existing operational capability.

SUMMARY: Three approaches were taken in this study: diagnostic modeling, data analysis, and prognostic modeling.

1) Diagnostic Modeling. Uncertainty in lateral open boundary conditions is the major problem for the coastal modeling. Diagnostic model (P-vector method) provides the simultaneous relationship between velocity and density fields, and in turn delivers a consistent open boundary conditions.

2) Data Analysis. The Navy's Master Oceanographic Observation Data Set (MOODS) with 200,000 T-S profiles in the South China Sea was analyzed using the parametric model (recently developed by PI and NAVOCEANO scientists), optimum interpolation, and the empirical orthogonal function (EOF) method.

3) Prognostic Modeling. The Princeton Ocean Model (Blumberg and Mellor, 1987) has been implemented for the South China Sea. The bottom topography was based on the NAVO-DBDB5. The model was initialized by the climatological T-S, and forced by the monthly varying winds (Hellerman and Rosenstein, 1983). The model runs exceptionally well under climatological forcing, and reveals a strong seasonal variation in the surface circulation and other features.

The results have been published in journals and proceedings, and presented at various conferences. Furthermore, along with the meteorologists, such as C.P. Chang, T.N. Krishnamurti, W.K. Lau, and M. Yanai, the principal investigator has also participated in the design of an international South China Sea Monsoon Experiment.

PUBLICATIONS:

Chu, P.C., Fralick, C.R., Haeger, S.D., and Carron, M.J., "A Thermal Parametric Model for the Continental Shelf," Journal of Marine Systems, in revision.

Chu, P.C., Wells, S.K., Haeger, S.D., Szczechowski, C., and Carron, M.J., "Temporal and Spatial Scales of the Yellow Sea Thermal Variability," Journal of Marine Systems, in revision.

Chu, P.C., Tseng, H.C., Chang, C.P., and Chen, J.M., "South China Sea Warm Pool Detected from the Navy's Master Oceanographic Data Set (MOODS)," Journal Of Geophysical Research, in revision.

Chu, P.C. and Fan, C.W., "Determination of Open Boundary Conditions from Interior Values," Journal of Atmospheric and Oceanic Technology, in revision.

Chu, P.C. and Fan, C.W., "Increment Vector Transfer Method for Determining Open Boundary Condition from Interior Values," Coastal Oceanic and Atmospheric Prediction, in press.

Chu, P.C. and Ehret, L.L., "Effects of Stratification and Continental Slope on the Shelf Break Isolation," Coastal Oceanic and Atmospheric Prediction, in press.

Chu, P.C., Tseng, H.C., and Chang, C.P., "South China Sea Warm-core and Cold-core Eddies Detected from the Navy's Master Oceanographic Observation Data Set," Global Ocean-Atmosphere-Land System, in press.

Chu, P.C., Huang, M.J., and Fu, E.X., "Formation of the South China Sea Warm-core Eddy in Boreal Spring," Global Ocean-Atmosphere-Land System, in press.

CONFERENCE PRESENTATIONS:

Chu, P.C. and Chang, C.P., "A Case Study of the South China Sea Warm Pool," International CLIVA-GOALS Workshop on Asian-Australian Monsoon Oceanography and Meteorology, Melbourne, Australia, 10-12 April 1995.

Chu, P.C. and Chang, C.P., "Feedback between South China Warm Pool and Asian Monsoon Onset," International Symposium on Climate Variability and Predictability, Melbourne, Australia, 10-12 April 1995.

Chu, P.C. and Chang, C.P., "South China Sea Warm Pool and Monsoon Development," invited, International South China Sea Monsoon Experiment (SCSMEX) Scientific Workshop, Beijing, China, 5-7 June 1995.

THESIS DIRECTED:

Tseng, H.C., LCDR, "South China Sea Warm-core and Cold-core Eddies Detected from the Navy's Master Oceanographic Observational Data Set (MOODS)," Master's Thesis, September 1995.

OTHER:

The results from the MOODS data analysis have been used by the Operations Directorate (N3T) of the Naval Oceanographic Office. The determination of open boundary conditions by the P-vector method will be used by Modeling and Techniques Department of the Naval Oceanographic Office.

Cai, W. and Chu, P.C., "A Thermal Oscillation under a Restorative Forcing," submitted to Journal of Physical Oceanography.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Nowcasting, forecasting, p-vector, diagnosis, geostropic forcing/flow

OCEAN OBSERVATIONS AND ANALYSIS

Peter C. Chu, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The long-term goal is to obtain a description of the large-scale circulation in the oceans. Determination of the general circulation is an important step toward understanding global climate, the distribution of chemical properties in the ocean, and the other problems.

The dynamics of large-scale circulation features such as the meandering, the gyres, and the recirculation of the Gulf stream is the focus of the research project. The purpose of the research is to seek an in-depth understanding of the dynamics and the ramifications of these features.

SUMMARY: Most knowledge of the general circulation of the world oceans is based on the classical dynamical method. Under the assumption of geostrophic balance, one computes the vertical shear of velocity from observed

hydrographic data. The major difficulty with this method is that there is missing constant of integration. This missing constant, the barotropic velocity, cannot normally be determined by direct means. The current inverse methods developed based on the geostrophic balance and mass conservation don't check the two ill-conditions: 1) no intersection between the isopycnal surface and the potential vorticity surface; and, 2)no beta-spiral turning. A new thrust is the effort to formulate the inverse problem for the calculation of absolute velocity from the T-S data with the ill-condition check-up.

A new inverse method (the P-vector method) with ill-condition check-up and error estimation has been developed to compute the North Atlantic ocean circulation from the climatological T-S data. Realistic ocean circulations were obtained using the P-vector method, which does not incorporate turbulent mixing, and the beta-spiral method, which does use turbulent mixing (Olbers et al. 1985). Both use the same climatological data (Levitus, 1982). This indicates that the main features of ocean general circulation is determined by the density field. The P-vector method leads to a better initialization scheme for ocean numerical models.

PUBLICATIONS:

Chu, P.C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," Journal of the Marine Technology Society, Vol. 29, No. 2, pp. 3-14, 1995.

Chu, P.C., "S-transform for Obtaining Localized Spectrum," Journal of Marine Technology Society, Vol. 29, in press.

Cai, W.J., and Chu, P.C., "Climate Variability and Drift under Simulated Flux Corrected Thermal Conditions," Journal of Climate, in press.

CONFERENCE PRESENTATIONS:

Chu, P.C. and Lozano, C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Lozano, C., and Fan, C.W., "A Regularized Inverse for Beta-spiral Dynamics," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Lozano, C. and Chu, P.C., "Ocean Circulation Analysis with Three Conserved Variables," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Fan, C.W., and Lozano, C.J., "P-vector Method for Assimilating Hydrographic Data into Ocean Circulation Models," American Geophysical Union Fall Meeting, San Francisco, CA, 12-16 December 1995.

OTHER:

Cai, W.J. and Chu, P.C., "Possible Effects of a Heat Flux Correction in Coupled Atmosphere-ocean Models," submitted to Geophysical Research Letters.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: P-vector, geostropic velocity

ANALYSIS OF THE U.S. NAVY'S MASTER OCEANOGRAPHIC OBSERVATION DATA SET (MOODS) FOR THE SHEBA EXPERIMENT

Peter C. Chu, Associate Professor
Robert H. Bourke, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objectives of the proposed research are to analyze more than 15,000 historical (1920-93) temperature and salinity profiles in the Beaufort Sea and surrounding seas for the most extensive data set available - the U.S. Navy's Master Oceanographic Observation Data Set (MOODS), to provide useful information for the refinement and optimization of the SHEBA experiment, and to develop an optimum thermal interpolation system for assimilating the 2-D (t,z) SHEBA data with the 4-D (t,x,y,z) MOODS data.

SUMMARY: Several approaches were taken in this study: 1) quality control of raw data; 2) water mass analysis, dividing the whole area into several sub-areas with characteristic profiles; 3) autocorrelation analysis of the T-S fields; 4) determination of temporal and spatial decorrelation scales for assessing oceanic thermocline and halocline; and, 5) development of an upper ocean thermohaline feature model for transforming each profile (MOODS or SHEBA) into a set of physical parameters, e.g., sea surface temperature (SST), sea surface salinity (SSS), depth of the maximum temperature, thermocline strength.

The results have been published (or submitted) in journals, technical reports, proceedings, and presented at various conferences. Furthermore, along with the polar scientists the principal investigators have participated the design of the SHEBA Experiment during the Intensive Observation Period (IOP).

The results from the MOODS data analysis have been transferred to the Operations Directorate (N3T) of the Naval Oceanographic Office. The technique of determining temporal and spatial decorrelation scales of the thermal variability was also used by the Naval Oceanographic Office.

PUBLICATION:

Chu, P.C., "A Feature Model for Arctic Upper Ocean Thermal Structure," Polar Meteorology and Oceanography, Vol. 4, pp. 224-227, American Meteorological Society, 1995.

CONFERENCE PRESENTATIONS:

Chu, P.C., "A Feature Model for the Arctic Upper Ocean Thermal Structure," American Meteorological Society Annual Meeting, Dallas, TX, 15-20 January 1995.

Brasket, A., Holland, M., and Chu, P.C., "Comparison of Arctic Ocean Mixed Layer Model with Observations," American Meteorological Society Annual Meeting, Dallas, TX, 15-20 January 1995.

Chu, P.C. and Bourke, R.H., "The Beaufort Sea Thermal Variabilities Detected from the Navy's MOODS Data," Invited, The SHEBA Ocean/Ice Working Group Meeting, Seattle, WA, 9-10 November 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Statistical structure, scales, optimal interpolation, ocean mixed layer, thermal feature model

CALIFORNIA UNDERCURRENT STUDIES

Curtis A. Collins, Professor
Newell Garfield, Research Assistant Professor
Everett Carter, Assistant Professor
Department of Oceanography
Sponsors: Naval Postgraduate School and Office of Naval Research

OBJECTIVE: To understand the dynamics and kinematics of the California Undercurrent off Central California. The following questions formed the basis for our investigation. What is the mean pattern of poleward and equatorward flow off Pt. Sur? What are the poleward transports of heat and salt? Is the California Undercurrent continuous along the west coast, or is it a series of discontinuous currents? Is there a reference level that can be used for geostrophic calculations: How can various velocity measuring techniques be used in a consistent manner?

SUMMARY: Past work involved 19 research cruises occupying a transection of CTD and Pegasus stations extending westward from Point Sur. Data from these cruises have been used to define the water mass structure and to determine the current structure between the coast and 200 km offshore. Work is now focused on understanding the dynamics of the California Undercurrent, the subsurface nearshore poleward flowing jet. Thirtyone RAFOS floats were launched in the eastern Pacific These data are being analyzed to determine the dynamics of the Undercurrent and the associated eddy field. We have also undertaken the task of restructuring the float processing software used by many members of the RAFOS community.

CONFERENCE PRESENTATION:

Garfield, N. and Collins, C.A., "Subsurface Velocity and Transport Measurements Off Central California," EPOC, Fallen Leaf Lake, CA, September 1995.

THESES DIRECTED:

Steiner, M., "Detiding Shipboard-mounted ADCP Data: An Analysis of Model Data and Observations using a Polynomial Interpolation Method," Master's Thesis, December 1994.

Benson, K.R., "High Frequency Subsurface Lagrangian Measurements in the California Current with RAFOS Floats," Master's Thesis, September 1995.

OTHER:

Collins, C.A., Garfield, N., Mascarenhas, A.S., and Spearman, M.G., "Ocean Current Measurements across the Entrance to the Gulf of California in April and December, 1992," under revision for Journal of Geophysical Research.

Collins, C.A., Garfield, N., Paquette, R.G., and Carter, E., "Lagrangian Measurements of Subsurface Poleward Flow along the West Coast of the United States during Summer, 1993," submitted to Geophysical Research Letters.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean circulation, absolute velocity measurements, eastern pacific circulation, Lagrangian subsurface circulation

OCEANOGRAPHY

LAGRANGIAN MEASUREMENTS IN A SUBSURFACE HYDROTHERMAL PLUME

Curtis A. Collins, Professor
Department of Oceanography
Sponsor: National Science Foundation and National Oceanic and Atmospheric Administration

OBJECTIVE: Measure the Lagrangian Path of a Hydrothermal Plume.

SUMMARY: This project was a high risk response to the opportunity to use three RAFOS floats to track a large hydrothermal water plume which emanated from the Juan de Fuca Ridge region. Risks included both locating the plume using ship-based instruments in order to launch the RAFOS floats into the plume, as well as the fact that the plume was located far from our sound sources so that navigation was questionable. Researchers were unable to locate the plume, however they did launch one RAFOS float in the expected plume vicinity. This float was submerged for a one year period (August 18, 1993 to August 11, 1994). During this time it remained between 640 and 680 db and underwent a net displacement of 220 km to the east-northeast. Although measurements of temperature and pressure were recovered from the float, subsurface navigation was not possible: either the ranges to the sound sources were too great or the hydrophone malfunctioned. The other two floats were launched at 1500m in the middle of our sound source array and are due to surface in December 1996.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: RAFOS, hydrothermal plume

OCEAN OBSERVATIONS AND ANALYSIS

Curtis A. Collins, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Obtain a long time series of currents over the continental slope.

SUMMARY: Current meter mooring "P2" is located at the 800m isobath off Point Sur, California, and has been maintained since May, 1989, by the Naval Postgraduate School. The mooring was cut by a trawler in March, 1995, all hardware was recovered, and data processed. The mooring was subsequently redeployed in July, 1995. Analysis of the time series at 350m was completed and submitted for publication.

OTHER:

Collins, C.A., Paquette, R.G., and Ramp, S.R., "Annual Variability of Ocean Currents at 350m-depth over the Continental Slope off Point Sur, California," submitted to 1996 CalCOFI Reports.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean currents

OCEANOGRAPHY

GLOBAL POSITIONING SYSTEM (GPS) ANTARCTIC LANDING SYSTEM: FLIGHT DATA EVALUATION AND ICE MOTION STUDY

James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Naval Command, Control and Ocean Surveillance Center, In-Service Engineering (NISE-West)

OBJECTIVE: The aircraft landing system at the US bases in Antarctica must be replaced in the next few years. GPS is the primary candidate system for use in this remote site. There are several special features about the local environment in polar latitudes that must be studied and validated before flight safety can be assured. The effort in 1995 evaluated the problem of ice motion and examined data from flight demonstrations.

SUMMARY: The runway at both McMurdo and South Pole stations are on ice that moves. The effects of this on a landing system utilizing differential GPS positions was studied. A differential GPS landing system generates absolute coordinates for the aircraft with respect to the center of the earth. If the landing field is moving, even slowly, then some adjustments must be made. Using data from three years surveys, it was found that the ice sheet at McMurdo is moving at about 30 cm/day. The motion has little or no vertical component, the most critical direction in a landing. The motion does mean that the runway position will have to be monitored on a continuing basis, and the touchdown coordinates used modified periodically. This will probably have to be done monthly.

Earlier a demonstration GPS landing system had been installed in NSF C130 aircraft and used at McMurdo and South Pole station for demonstrations. In 1995 this program was continued with two improvements: a second GPS system was installed on the aircraft and the ground that collected raw measurements for post processing and a "stepped" approach was installed in the landing plan. This system was tested at Pt. Mugu Naval Air Station and deployed to Antarctica. While there data was acquired at McMurdo. The program was successful in all aspects. The improved landing system worked well and data from the auxiliary GPS systems provided a 1 m trajectory of the aircraft to verify this.

THESIS DIRECTED:

Eipp, T.B., "Differential GPS for Precision Approach: Commercial Technology and Navy/Marine Corps Requirements," Master's Thesis, 1995.

DOD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics, Sensors

KEYWORDS: GPS, landing systems

GLOBAL POSITIONING SYSTEM ADVANCED TECHNIQUES

James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Defense Mapping Agency

OBJECTIVE: The objective of this project is to investigate methods of utilizing Global Positioning System to enhance the acquisition of geographic positions.

SUMMARY: The DOD has purchased a huge number of small GPS receivers known as the Precision Lightweight GPS Receiver (PLGR) for all services. This will likely be the "receiver of opportunity" in quick reaction events. It was not intended to provide geodetic quality results however. The characteristics of this receiver were investigated to determine its potential and techniques developed for improving the accuracy of its coordinates.

Several sets of data in controlled static environments as well as in slow moving vehicles were acquired. These were analyzed. It was found that moderately accurate positions (20 cm level) could be obtained even under low dynamic conditions utilizing data provided at the computer interface port of the PLGR.

This work also pointed up some generic characteristics of Precise Positioning Service (PPS) GPS solutions which will have and influence on using any PPS receiver.

DOD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: GPS

GPS AIRBORNE PRECISION APPROACH RADAR VALIDATION SYSTEM

James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Naval Command, Control and Ocean Surveillance Center, In-Service Engineering (NISE-West)

OBJECTIVE: The objective of this project is to design a low cost GPS system with off the shelf equipment that can be used to validate at the 1 m level Navy Precision Approach Radar performance and demonstrate that system.

SUMMARY: The requirements for this system require that both a set of flight data and the supporting ground surveys. In addition the flight data analysis system should be compatible with that used in earlier programs by NISE West. These requirements were met with Ashtech MD-XII receivers. These were obtained and used in the development and demonstration of the system. Off the shelf survey post processing software was not provided as it is available from the vendor directly and not needed for the system development.

Much of the work went into determining how to utilize the equipment and development of the software to provide a direct analysis of the radar performance. This was done and the system was tested at Pt. Mugu Naval Air Station in September 1995. A Naval Postgraduate School trajectory generation program was adapted to this project in order to allow the use of different receivers in flight testing.

PUBLICATION:

Sagavoc,C.P., Danielson, D.A., Clynch, J.R., and Neta, B., "Fast Interpolation for Global Positioning System (GPS) Satellite Orbits," Naval Postgraduate School Technical Report, NPS-MA-95-006, August 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Air Vehicles, Electronics

KEYWORDS: GPS, landing systems, precision approach radars

SIMULATION OF LAGRANGIAN DRIFTER RESPONSE TO LABRADOR SEA CONVECTION

Roland W. Garwood, Jr., Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: This project is part of the ONR Accelerated Research Initiative (ARI) on Oceanic Convection in the Labrador Sea. The objective for the next two years of this modeling component of the ARI is to simulate Lagrangian drifter response to oceanic convection. A large-eddy simulation (LES) model will be used to predict the fully-turbulent

nonhydrostatic evolution of the oceanic flow fields that are typical of the Labrador Sea. These 4-dimensional fields will be archived and used to force a variety of Lagrangian drifter models (LDMs). LDMs that are currently being designed will be used to test strategies and combinations of drifter types to best achieve the overall scientific objectives for the ONR Convection ARI in the Labrador Sea.

SUMMARY: Progress during the first phase of this project includes: Analytical analysis of the enhanced buoyancy flux due to the pressure-augmentation of thermal expansion of sea water led to the prediction of a probable mid-depth maximum in the turbulent kinetic energy (TKE) for free oceanic convection in the polar seas whenever the mixed layer depth exceeds about 1 km. A new class of oceanic conditional instability was also predicted. The instability has two forms: a "parcel instability" and a "layer instability." For these suspected phenomena, the vertical transport of heat and mass in the polar seas are hypothesized to resemble convection in the tropical atmosphere, because of the mathematical similarity with conditional instabilities in the atmosphere. This discovery is significant because it is a possible mechanism for the initiation of the global thermohaline conveyor belt with deep water formation in the Greenland-Iceland Seas and in the polar southern oceans. These analytical predictions have now been confirmed with large-eddy simulation (LES).

Satellite imagery was shown to include the surface signature of mesoscale oceanic convection cells resembling Rayleigh-Benard cells in the Greenland Sea during winter. Numerical solutions for convection-driven surface velocity have been archived and provided to other ONR PIs as input for a radar model to evaluate the potential of using radar imagery to remotely detect surface heat fluxes and evidence of deep convection.

Wind stress has been included in LES cases. Unsteady Langmuir-like circulation was predicted for cases of strong forced convection and relatively weaker free convection. Lagrangian Drifter Models (LDMs) have been developed for both pure Lagrangian drifters and for isobaric drifters (Rossby floats). Improved numerical solutions (using predictor-corrector algorithms) for LDM motion within the LES domain have been developed and are being tested. LDMs are presently being inserted into LES cases with different surface forcing - surface cooling only, mixed wind stress and surface cooling, and unsteady surface forcing cases. Finally, larger-scale bottom plume instabilities have been predicted for the Denmark Strait and inflow into the Labrador Sea. These hydrostatic, free-surface PE model solutions will help span the scale domain between the LES and basin-model scales for the Labrador Sea Convection ARI, and for the Lagrangian drifter applications to intermediate scales (5 km - 50 km).

PUBLICATIONS:

Jiang, L. and Garwood, R.W., Jr., "A Numerical Study of Three-dimensional Dense Bottom Plumes on a Southern Ocean Continental Slope," Journal of Geophysical Research-Oceans, Vol. 100, pp. 18471-18488, 1995.

Jiang, L. and Garwood , R.W., Jr., "Three-dimensional Simulations of Overflows on Continental Slopes," Journal of Physical Oceanography, Vol. 25, 52 pp., in press.

CONFERENCE PRESENTATIONS:

Garwood, R.W., Jr. and Harcourt, R., "The Polar Seas: A Laboratory For Deep Ocean Convection," Invited talk, in XXII IAPSO Proceedings Abstracts, p. 154, Honolulu, HI, 5-12 August 1995.

Garwood, R.W., Jr. and Harcourt, R., "Response Of Deep Ocean Convection To Transient Forcing," Invited talk, ONR Labrador Sea Workshop, Washington DC, 30 October - 1 November 1995.

Guest, A. and Garwood, R.W., Jr., "Parameterization Of The Equatorial Entrainment Zone," in XXII IAPSO Proceedings Abstracts, p. 229, Honolulu, HI, 5-12 August 1995.

THESES DIRECTED:

Bedell, K., "Detection of Oceanic Convection Utilizing Submarine-observed Acceleration," Master's Thesis, June 1995.

Johnson, J.C., "Turbulent Heat Flux Measurements over the Greenland, Norwegian and Barents Seas," Master's Thesis, March 1995.

OTHER:

Guest, A., Garwood , R.W., Jr., and Harcourt, R., "Oceanic Planetary Boundary Layer (OPBL) Home Page," (revised) on the Internet, at http://www.oc.nps.navy.mil/~bird/, 1995.

DOD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles, Environmental Quality, Computing and Software

KEYWORDS: Air-sea interaction, convection, ocean turbulence, Lagrangian measurements

TROPICAL OCEAN MIXED LAYER SYSTEM

Arlene A. Guest, Oceanographer
Roland W. Garwood, Jr., Professor
Department of Oceanography
Sponsors: National Oceanic and Atmospheric Administration and National Science Foundation

OBJECTIVE: This three-year project is part of the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE). This TOGA COARE grant to NPS is for determining the essential forcing and physical processes for the tropical ocean turbulent boundary layer system, using a hierarchy of three numerical ocean models in conjunction with observations of the atmospheric forcing and the upper ocean response. These models include physical processes that have been neglected or unrealistically parameterized in previous studies.

SUMMARY: Progress during the first year of this project includes the development and testing of a one-dimensional model, OPBL1D. This NPS bulk turbulence closure oceanic planetary boundary model has a unique entrainment zone parameterization. This has demonstrated that including entrainment zone physics in tropical ocean prediction is crucial for representing the deep penetration of turbulent fluxes of energy and momentum into the equatorial thermocline

(Guest and Garwood, 1995; Garwood and Guest, 1996, in preparation). Microstructure measurements are being used from the Tropic Heat Experiment to verify the mixed layer model results.

Extensive development of the three-dimensional embedded ocean general circulation-mixed layer model, OGCM/ML, has been accomplished this past year. The improvement in the horizontal friction formulation from Laplacian to biharmonic has allowed much more realistic representation of mesoscale waves and eddies which modulate the entrainment zone activity, with the entrainment zone mixing depending on the shear enhancement or reduction attributable to the mesoscale motion. Results from this improved primitive equation/mixed layer model were presented at the IAPSO meeting in August, 1995 (Guest and Garwood, 1995). The simulations with new entrainment zone parameterization improve the representation of sea surface temperature and the vertical distribution of heat. It was also found that large-basin (20 S - 20 N, 140 E - 110 W), 25 km grid resolution simulations are necessary for both realistic mesoscale circulation and undercurrent evolution, especially when using real surface forcing data. The diurnal cycle in heat flux needs to be included for realistic vertical transport of heat and momentum.

The Large-Eddy Simulation (LES) model has been used to simulate the equatorial turbulent boundary region and contrast the turbulence statistics with those derived from mid-latitude simulations. Langmuir-like circulations have been shown (Garwood and Harcourt, 1995) to develop for mid-latitude cases, even in the absence of surface gravity wave physics. The Langmuir circulations predicted by the LES are expected to change their structure with reduced rotation (high Rossby number). The LES model has also been used to verify the constants used in the turbulence closure scheme of the 1-D and 3-D mixed layer models.

Data sets have been acquired for model forcing and verification. The 1961-1992 FSU Pacific wind stress climatology was used to force the OGCM/ML model. Also, the FSU wind stress analyses for individual years was acquired and is planned for use. The Esbensen-Kushnir heat flux climatology data for the Pacific was used to force the model.

PUBLICATIONS:

Garwood, R.W., Jr. and Harcourt, R., "The Polar Seas: A Laboratory For Deep Ocean Convection," Invited talk, XXII IAPSO Proceedings Abstracts, p. 154, Honolulu, HI, 5-12 August 1995.

Guest, A. and Garwood, R.W., Jr., "Parameterization Of The Equatorial Entrainment Zone," XXII IAPSO Proceedings Abstracts, p. 229, Honolulu, HI, 5-12 August 1995.

OTHER:

Guest, A., Garwood , R.W., Jr., and Harcourt, R., "Oceanic Planetary Boundary Layer (OPBL) Home Page," (revised) on the Internet, at http://www.oc.nps.navy.mil/~bird/, 1995.

DOD KEY TECHNOLOGY AREAS: Modeling and Simulation, Environmental Quality, Computing and Software

KEYWORDS: Air-sea interaction, ocean turbulence, equatorial circulation

NONLINEAR INTERACTIONS IN OCEAN SURFACE WAVES

Thomas H. C. Herbers, Assistant Professor
Department of Oceanography
S. Elgar, Washington State University
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this continuing project is to evaluate the importance of nonlinear interactions in naturally occurring ocean surface waves.

SUMMARY: Although sophisticated nonlinear theories for ocean surface waves were developed more than 30 years ago, a detailed verification with field observations has not been reported. In this continuing project extensive ocean wave data sets are compared to nonlinear theory predictions. At about three times the frequency of the dominant wind waves, tertiary waves forced by nonlinear interactions between three wind-wave components are important. Trispectral analysis of data collected during a severe nor'easter (the significant wave height was about 5 m) indicates significant tertiary wave contributions to the bottom pressure field.

PUBLICATIONS:

Elgar, S., Herbers, T. H. C., Chandran, V., and Guza, R. T., "Higher-order Spectral Analysis of Nonlinear Ocean Surface Gravity Waves," Journal of Geophysical Research, Vol. 100, No. C3, pp. 4977-4983, 1995.

Elgar, S., Herbers, T. H. C., and Guza, R. T., "Nearshore Observations of Nonlinear Ocean Surface Gravity Waves," Naval Research Reviews, in press.

CONFERENCE PRESENTATION:

Elgar, S., Guza, R. T., Raubenheimer, B., Herbers, T. H. C., and Gallagher, E., "Observations of Wave Evolution during Duck94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

OTHER:

Elgar, S., Guza, R. T., Raubenheimer, B., Herbers, T. H. C., and Gallagher, E., "Spectral Evolution of Shoaling and Breaking Waves on a Barred Beach," to be submitted to the Journal of Geophysical Research.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean surface waves, nonlinear interactions, sea floor pressure

BOTTOM PRESSURE FLUCTUATIONS ON THE SHELF INDUCED BY SURFACE WAVES

Thomas H. C. Herbers, Assistant Professor
Department of Oceanography
R.T. Guza, Scripps Institution of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this continuing project is to determine the mechanisms by which nearshore infragravity waves are generated.

SUMMARY: Infragravity waves or 'surf beats' are waves with periods of nominally 0.5-5 minutes that are believed to cause changes in beach morphology and drive seiche motions in small harbors. Although the generation of infragravity waves has been linked to shoaling wind waves, the precise mechanisms are not understood. Observations in depths between 8-204 m, near Atlantic and Pacific coasts, were used to show that infragravity waves are a mix of forced waves, locally excited by nonlinear wave-wave interactions, and free waves generated at nearby shores. Although free waves usually dominated the infragravity band, forced wave contributions were significant with large amplitude swells and in very shallow water. Observed forced wave energy levels were shown to be accurately predicted by second-order nonlinear theory. A geometrical optics-based model was developed for the generation and propagation of free infragravity waves. Model predictions are in good agreement with the observations. Free infragravity energy levels are sensitive to the geographic surroundings. Comparisons of observations made on different shelves, suggest that more infragravity energyis generated on broad, sandy beaches than on rocky, cliffed coasts.

PUBLICATION:

Herbers, T.H.C., Elgar, S., Guza, R. T., and O'Reilly, W. C., "Infragravity-frequency (0.005-0.05 Hz) Motions on the Shelf, Part II: Free Waves," Journal of Physical Oceanography, Vol. 25, No. 6, pp. 1063-1079, 1995.

Herbers, T.H.C., Elgar, S., and Guza, R.T., "Generation and Propagation of Infragravity Waves," Journal of Geophysical Research, Vol. 100, No. C12, pp. 24863-24872, 1995.

CONFERENCE PRESENTATION:

Evangelidis, D., Herbers, T. H. C., Jessen, P. F., Elgar, S., O'Reilly, W. C., and Guza, R. T., "Wave Propagation across the Continental Shelf. 2. Infragravity Waves," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean surface waves, continental shelf, nearshore processes

SHALLOW WATER WAVE PROCESSES

Thomas H. C. Herbers, Assistant Professor
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The overall objective of this research is to predict accurately nearshore wave and surf processes.

SUMMARY: A new method was developed for estimating the reflection of ocean waves from coastal structures (e.g., breakwaters, seawalls) or natural shores (e.g., sand bars, steep foreshores) using a spatial array of instruments located seaward of the reflector. Whereas earlier studies assumed unidirectional waves propagating perpendicular to the reflector, the new technique is applicable to a realistic multi-directional sea. Model tests with simulated array data demonstrate that the gross properties of incident and reflected waves can be accurately estimated for wave incidence angles up to about 30 degrees.

The new method was applied to array data acquired offshore of a permeable, rubble mound breakwater in Monterey Bay, California. The estimated reflection coefficients are only weakly dependent on the wave energy but decrease with increasing wave frequency. The observed fraction of the incident wave energy flux that is transmitted through the breakwater decreases with increasing incident wave energy flux, suggesting that dissipation is enhanced with large amplitude waves.

PUBLICATION:

Dickson, W.S., Herbers, T.H.C., and Thornton, E.B., "Wave Reflection from a Breakwater," Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 121, No. 5, pp. 262-268, 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean surface waves, coastal structures, nearshore processes

PROPAGATION OF SURFACE WAVES ACROSS THE CONTINENTAL SHELF

Thomas H.C. Herbers, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The overall objective of this project is to evaluate and improve model predictions of the evolution of swell propagating across a continental shelf.

SUMMARY: The propagation of surface gravity waves over a wide, shallow continental shelf was investigated with data collected in the recent DUCK94 Nearshore Field Experiment. Four-month-long seafloor pressure records were obtained with a cross-shore array of 20 bottom-mounted and moored pressure sensors extending from the shoreline to the shelf break (87 m depth, 100 km from shore). Directional wave data were collected with a coherent array of pressure sensors in 8 m depth, 1 km from shore (deployed and maintained by the Army Corps of Engineers), and a 3-m discuss buoy in 50 m depth, 100 km from shore (deployed and maintained by the National Data Buoy Center). The measurements span a wide range of conditions including several nor'easters, very energetic swells from Hurricane Gordon (maximum significant wave height 8 m), and periods of extremely low wave energy (minimum significant wave height 0.2 m). When swell energy levels are low or moderate, the swell energy varied weakly across the shelf, consistent with predictions of a linear propagation model. The attenuation of swell by dissipation (e.g., bottom friction or whitecapping) or scattering processes appears to be weak. During high-energy conditions, strong nonlinear interactions and wave breaking caused a dramatic evolution of wave spectra across the inner shelf.

CONFERENCE PRESENTATION:

Hendrickson, E. J., Herbers, T.H.C., Jessen, P.F., O'Reilly, W.C., and Elgar, S., "Wave Propagation across the Continental Shelf. 1. Swell," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean surface waves, continental shelf, swell

NEARSHORE WAVE PROCESSES

Thomas H. C. Herbers, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to develop a better understanding of the nonlinear transformation of waves shoaling on beaches.

SUMMARY: As ocean surface waves propagate from deep to shallow water, nonlinear wave-wave interactions transfer energy to phase-coupled harmonics, causing the characteristic steep, pitched-forward wave crests on beaches. A stochastic shoaling model for directionally spread wind waves propagating over a gently sloping beach with straight and parallel depth contours was developed based on weakly dispersive Boussinesq theory. A numerical implementation is currently underway.

CONFERENCE PRESENTATIONS:

Herbers, T. H. C., Burton, M. C., Elgar, S., and Guza, R. T., "Directional Spreading Effects on Shoaling Waves," Coastal Dynamics'95: An International Conference on the Role of Large Scale Experiments in Coastal Research, Gdansk, Poland, 4-8 September 1995.

Feddersen, F., Guza, R.T., Elgar, S., and Herbers, T.H.C., "Observations of Nearshore Currents in Duck94," Coastal Dynamics'95: An International Conference on the Role of Large Scale Experiments in Coastal Research, Gdansk, Poland, 4-8 September 1995.

Feddersen, F., Guza, R.T., Elgar, S., and Herbers, T.H.C., "Observations of Longshore Current in Duck94/CooP," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

THESIS DIRECTED:

Burton, M.C., LCDR, USN, "Directional Spreading Effects on Nonlinear Waves Shoaling on Beaches," Master's Thesis, June 1995.

OTHER:

Herbers, T.H.C., and Burton, M.C., "Nonlinear Shoaling of Directionally Spread Waves on a Beach," submitted for publication in the Journal of Fluid Mechanics.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean surface waves, nearshore processes, surf on beaches

NUMERICAL STUDY OF OVERFLOW PLUMES

Lin Jiang, Research Associate
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The scientific objective of this proposed two-year study is to understand the three-dimensional features, instabilities, topographic steering effects and variability of the climatically most important overflow in the North Atlantic, the Denmark Strait Overflow. Earlier stream-tube type models of overflow plumes exclude some processes that are found to be very important [Jiang and Garwood, 1995a, b, 1996]. The roles of turbulent mixing and entrainment, bottom friction, the stratification, topography, variations in the sources water, and large-scale circulation will be determined in the processes of descending and interleaving of the Denmark Strait Overflow plumes. An important goal is to use the 3-D numerical results to provide more physically consistent parameters for mixing and entrainment, so that simple parameterizations of overflow plumes can be developed for large-scale ocean circulation models for global climate study. The ultimate goal is to establish a quantitative relationship between the surface cyclonic eddies and the bottom overflow plumes in the Denmark Strait Overflow region. Once this quantitative relationship is established, it may be possible to use satellite altimetry and AVHRR to monitor the Denmark Strait Overflow, which produces most of the North Atlantic Deep Water.

SUMMARY: Three-dimensional features and instabilities of dense overflows from marginal seas onto continental slopes are investigated using a three-dimensional, primitive equation numerical ocean model. The numerical simulations reveal important instability and three-dimensional features of the overflow plumes that has not included in early simulations with a one-dimensional stream-tube model and a two-dimensional plume model. It is shown that the large primary plume breaks into a number of smaller sub-plumes on the offshore side of the plume due to instabilities which are manifested as growing topographic Rossby waves over the slope. The observed high temporal and spatial variabilities in the Denmark Strait Overflow could be caused by the inherent dynamic instabilities as revealed by the numerical simulations. The simulations indicate that the initial overflow velocity and width, the properties of the source water, the planetary rotation, and the slope steepness play major roles in determining the scales of the breaking-away sub-plumes and the across-slope penetration of the large plume. The model simulations also show that a chain of surface cyclonic eddies form and travel almost parallel to the isobaths toward the right and downstream of the plumes' source. These eddies provide a surface signature of the sinking, breaking-away sub-plumes, as a result of vortex stretching in the upper part of the water column. Such surface features may have been observed in satellite IR imagery along the East Greenland continental shelfbreak by Bruce (1995), and it may be possible to use satellite imagery to monitor the Denmark Strait Overflow, which produces most of the North Atlantic Deep Water.

PUBLICATIONS:

Jiang, L. and Garwood, R.W., "A Numerical Study of Three-dimensional Bottom Plumes on a Southern Ocean Continental Slope," Journal of Geophysical Research, Vol. 111, No. C9, pp. 18471-18488, 1995.

Jiang, L. and Garwood, R.W., "Three-dimensional Simulations of Overflows on Continental Slopes," Journal of Physical Oceanography, in press.

OTHER:

Jiang, L. and Garwood, R.W., " Effects of Topography and Ambient Stratification on Overflow Plumes over Continental Slopes," submitted to Journal of Geophysical Research.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Overflows, modeling, climate change, mixing, entrainment

NUMERICAL MODELING OF MONTEREY BAY CIRCULATION

Lin Jiang, Research Associate
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The objective of this research is to develop a nowcast/forecast system of the Monterey Bay (MOB) for the Navy based on a state-of-the-art coastal ocean model (Princeton Ocean Model-POM), data assimilation and a grid generation techniques. The grids used in this study are both orthogonal (rectangular) and curvilinear, coastline-following, nearly-orthogonal which are designed using grid generation technique (GGT). These grids are designed using grid generation technique which improve numerical model efficiency by packing grid where necessary, without increasing the total number of grid points. The data is from all sources, such as satellite products and in situ observations, and includes fields for currents, sea surface heights, temperature, salinity, waves, and tides. Various data assimilation schemes are to be tested in the MOB model simulation.

SUMMARY: A coastal ocean sigma coordinate model of Monterey Bay with realistic bottom topography and coastlines is developed using the Princeton Ocean Model (POM) and a grid Generation Technique (GGT) to study the horizontal pressure gradient errors associated with the MOB steep topography. The submarine canyon in MOB features some of the steepest topography encountered anywhere in the world's oceans. The MOB model is tested with both orthogonal and curvilinear nearly-orthogonal (CNO) grids. The CNO grid has horizontal resolution which varies from 300 m to 2 km, while the resolution of the orthogonal grid is uniform with δx=1.25 km and δy=1.38 km. These grids cover a domain of 180 x 160 km with the same number of grid points of 131 x 131. Vertical resolutions of 25, 35 and 45 vertical sigma levels are tested. The truncation error in the MOB models are evaluated in terms of mean kinetic energy and velocity against various grids, vertical, horizontal resolution and σ distributions, and bottom topography smoothing.

Simulations with various grids show that the GGT can be used as another tool in reducing σ coordinate errors in coastal ocean modeling besides increasing resolution and smoothing bottom topography. A CNO grid with a high grid density packed along steep slopes and Monterey Submarine Canyon reduces the errors by 40 % compared to a rectangular grid with the same number of grid points. The CNO grid is more efficient than the rectangular grid, since it has most of its grids over water. The simulations also show that the vertical resolution with 45 levels reduces the volume-averaged

mean kinetic energy (KE) due to truncation error by 55% in comparison with 25 vertical levels. The steep and complicated topography of the MO, where the maximum topographic factor is equal to 0.55, needs to smoothed to

$$TF = \sqrt{(\partial H/\partial x)^2 + (\partial H/\partial y)^2}$$

maximum. TF=0.24 to reduce 60 % of the KE without losing the important topographic features. Experiments with 0.55, needs to be smoothed to maximum TF=0.24 to reduce 60 % of the KE without losing the important topographic features. Experiments with three different σ-distributions (each with 45 vertical levels) confirm that a log distribution of σ in surface and bottom boundary layers has an velocity error of 11 % smaller than two other (uniform σ and surface log σ distributions). The presented MOB σ coordinate model can be used with confidence regarding horizontal pressure gradient error.

CONFERENCE PRESENTATION:

Ly, L.N, and Jiang, L., "On the Pressure Gradient Error in the Monterey Bay Sigma Coordinate Ocean Model," AGU Fall Meeting, San Francisco, CA, December 1995.

OTHER:

Ly, L.N and Jiang, L., "The Pressure Gradient Errors of the Monterey Bay Sigma Coordinate Ocean Model with Various Grids," submitted to Journal of Geophysical Research.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal ocean modeling, grid generation, data assimilation

AIR-SEA-WAVE INTERACTION

Le Ngoc Ly, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: This multi-year project is expanded from the ONR sponsor under Marine Boundary Layer Program, "Effects of Ocean Surface Waves on Fluxes and Turbulence and Resulting Impacts on Coupling Modeling." The problem to be solved in this project is one aspect of air-sea-wave interaction modeling, which includes air-sea-wave model development of semi-empirical turbulence theory and application of a new theory, the wave boundary layer (WBL) theory, to air-sea-wave coupling. The goal of this project is also to apply the developed models, theory to larger scale ocean and atmospheric models.

SUMMARY: In FY95 the focus was on using recently developed air-sea-wave interaction models of semi-empirical turbulence theory (Ly, 1995) for studying energy and momentum transfer in the air-sea system, and investigating influences of waves on air-sea fluxes, turbulent structure (including turbulence kinetic energy budget and dissipation distributions), dynamical structure of atmospheric/oceanic boundary layers, and air-sea interaction characteristics. The work in FY95 also focused on validation of numerical model results by comparison to available datasets. The result of the study is published in a new series of publications.

PUBLICATION:

Ly, L.N., "A Numerical Coupled Model for Studying Air-Sea-Wave Interaction," Journal of Physics of Fluid, Vol. 7, No. 10, pp. 2396-2406, 1995.

OTHER:

Ly, L.N., "A Pivotal-Condensation Method for a Mathematical Coupled Model of the Air-Sea-Wave System," Mathematical and Computer Modelling, in review.

Ly, L.N., "A Numerical Study of Aerodynamic Roughness Lengths as Seen from Above and Below in Air-Sea-Wave Coupling," submitted to Journal of Physical Oceanography.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Other (Environmental Physics & Software, New Technique)

KEYWORDS: Ocean wave effects, air-sea-wave theory, air-sea-wave modeling, air-sea interaction, boundary layers, environmental turbulence

COASTAL OCEAN MODELING

Le Ngoc Ly, Research Associate Professor
Department of Oceanography
Sponsors: Office of Naval Research

OBJECTIVE: Research is for the development of a capability to derive analyzed time varying ocean fields in coastal environments based on available data and ocean dynamics. The data is from all sources, such as satellite products and in situ observations, and includes fields for currents, sea surface heights, temperature, salinity. The coastal models are developed based on the most recent version of the Princeton Ocean Model (POM), grid generation and multi-block grid techniques , and data assimilation techniques. The models have curvilinear, nearly-orthogonal, coast-following grids, to better simulate regions with complicated coastlines, bathymetry, and boundary conditions. The model has complete thermodynamics and mixed layer physics.

A key component of the research is to perform a system which will produce the 4-D analyzed ocean structure for the Monterey Bay (MB), and South China Sea (SCS) as a prototype for a Navy system of coastal environments using available data from all sources, data assimilation technique and coastal ocean models. This capability also allows for the generation of virtual coastal oceans useful for various applied sciences, including undersea acoustic and environmental applications.

SUMMARY:

Monterey Bay Modeling: This multi-year project is also an application of grid generation, multi-block grid techniques of Computational Fluid Dynamics (CFD) to the Monterey Bay (MOB) modeling. The research is to develop a coastal ocean system for the MOB which couples a state-of-the-art coastal ocean model to a grid package of curvilinear nearly-orthogonal grids to better handle complex coastlines and topography. The research is also to develop a system of capability in producing nowcasts/forecasts based on available data using data assimilation techniques. This is be done in combination with a coastal modeling effort using a state-of-the-art coastal model, the Princeton Ocean Model (POM), and Grid Generation Technique (GGT). FY95 mode of the project emphasizes nowcasts. The developed MOB nowcast system is used in study of the horizontal pressure gradient errors in the MOB sigma coordinate ocean model.

South China Sea Nowcast/Forecast System: The multi-year project is to develop a nowcast/forecast capable system for the South China Sea (SCS) using a state-of-the-art coastal ocean model. The model was developed based on the most recent version of the POM. The SCS model is a curvilinear, nearly-orthogonal, coast-following grids and fully active thermodynamics to better simulate regions with complicated coastlines, bathymetry, and boundary conditions. In the

FY95 mode of the project, the nowcast system for the SCS is developed and used in a sensitivity study of numerical solutions of the SCS ocean model to various grids using GGT. In FY96 the research will be to develop forecast capability system focusing on monsoons and wind wave effects.

PUBLICATIONS:

Ly, L.N and Luong, P., "Application of Grid Generation Techniques to the Yellow Sea Simulation," High Performance Computing and Communication (HPC-ASIA 1995), Electronic Proceedings, Taipei, Taiwan, 1995.

Ly, L.N. and Jiang, L., "On the Pressure Gradient Error in the Monterey Bay Sigma Coordinate Ocean Model," American Geophysical Union (AGU), San Francisco, CA, Transactions, O42B-4, No. 45, 1995.

Luong, P. and Ly, L. N., "Application of the Multi-block Grid Technique in Coastal Ocean Modeling: the Mediterranean Simulation," American Geophysical Union (AGU), San Francisco, CA, Transactions, O42B-9, No. 45, 1995.

Ly, L.N. and Tran, V., "A Sensitivity Study of Numerical Solutions of the South China Sea Ocean Model to Various Grids," American Geophysical Union (AGU), San Francisco, CA, Transactions, O41B-2, No. 45, 1995.

Ly, L.N. "High Performance Computing in Coastal Ocean Modeling," invited, Taipei, Taiwan, 1995.

Ly, L.N, Luong, P., O'Connor, W. P., Ezer T., and Mellor, G. L., "A Numerical Study of Circulation and M2 Tide in the Yellow Sea," European Geophysical Society, XX General Assembly, Hamburg, Germany, 1995.

THESIS DIRECTED:

Tran, V., "A Sensitivity Study of Numerical Solutions of the South China Sea Curvilinear Ocean Model to Grids Using Grid Generation Technique," Master's Thesis, December 1995.

OTHER:

Ly, L.N. and Jiang, L., "The Horizontal Pressure Gradient Error in the Monterey Bay Sigma Coordinate Ocean Model," submitted to Journal of Geophysical Research, 1995.

DOD KEY TECHNOLOGY AREAS: Environmental Quality, Modeling and Simulation, Other (Data & Software, New Technique)

KEYWORDS: Nowcast/Forecast systems, data-model combination, coastal ocean modeling, grid generation techniques, data assimilation

REMOTE SENSING AND VALIDATION OF COASTAL CURRENTS FROM HIGH FREQUENCY (HF) RADAR

Jeffrey D. Paduan, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this program is to evaluate high frequency radar measurements of ocean surface currents for use in operational coastal monitoring situations and in numerical model validation and assimilation.

SUMMARY: This project is part of a larger effort to operate a network of CODAR-type HF radars around the shores of Monterey Bay and process surface current data. Several month-long time series measurements from three radar sites

were collected in 1994 and 1995. Validation efforts were undertaken that compared radar-derived currents with in situ observations from a moored current meter, drifting buoys, and vessel-mounted acoustic Doppler current profiles. This particular effort focused on supporting numerical modeling projects taking place in Monterey Bay with surface current data for model verification and data assimilation. A unique application of the Princeton Ocean Model was run under this project to study tidal currents in Monterey Submarine Canyon and compare results with HF radar currents. Detailed bathymetric and hydrographic data from the region was assembled for this effort and also made available to collaborating modeling investigators at the Naval Postgraduate School and Hydroqual, Inc.

PUBLICATION:

Paduan, J.D., Petruncio, E.T., Barrick, D.E., and Lipa, B.J., "Surface Currents within and Offshore of Monterey Bay as Mapped by a Multiple-site HF Radar (CODAR) Network," Proceedings of the IEEE Fifth Working Conference on Current Measurement, pp. 137-142, St. Petersburg, FL, 7-9 February 1995.

CONFERENCE PRESENTATIONS:

Paduan, J.D., Petruncio, E.T., Barrick, D.E., and Lipa, B.J., "Surface Currents within and Offshore of Monterey Bay as Mapped by a Multiple-site HF Radar (CODAR) Network," IEEE Fifth Working Conference on Current Measurement, St. Petersburg, FL, 7-9 February 1995.

Paduan, J.D., Rosenfeld, L.K., Cook, M.S., and Anderson, T. "Remotely Sensed Surface Currents in Monterey Bay from Shore-based HF Radar (CODAR)," 42nd Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 26-29 September 1995.

Petruncio, E.T., Rosenfeld, L.D., and Paduan, J.D., "Observations and Modeling of Tidal Currents in a Submarine Canyon," 42nd Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 26-29 September 1995.

THESIS DIRECTED:

Melton, D.C., "Remote Sensing and Validation of Surface Currents from HF Radar," Master's Thesis, September 1995.

OTHER:

A unique demonstration experiment was organized by the principal investigator in which two OSCR-type (phased-array) HF radar systems were operated in Monterey Bay during May 1995 under the sponsorship of the radar manufacturer. The only existing side-by-side observations from OSCR-type and CODAR-type radar systems was obtained through this effort.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: HF radar, ocean currents, Bragg Scatter, data assimilation

LAGRANGIAN MEASUREMENTS OF EDDY CHARACTERISTICS IN THE CALIFORNIA CURRENT

Jeffrey D. Paduan, Assistant Professor
Department of Oceanography
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This project is part of an ongoing effort to observe mean and eddy currents in the ocean off the U.S. west coast using satellite-tracked drifting buoys. The long-range goal is to develop forecast models for the formation, movement, and decay of ocean eddies.

SUMMARY: This program is part of a larger coordinated effort to study the eddy field in an eastern boundary current sponsored by the Office of Naval Research. Field observations took place in 1993 and 1994 with quarterly deployments of eight surface drifters placed along an offshore line at 39.5 degrees north latitude (39.5N). The first instruments were placed at 125 degrees west longitude (125W) with approximately 40 km between subsequent deployment sites. The second component of the experiment involved intensive study of one cyclone and one anticyclone to expose flow structures and decay rates. This year's focus has been on the analysis of trajectories from the heavily sampled anticyclone. A method was developed and implemented to filter high frequency inertial motions from the trajectories in order to avoid aliasing them into estimates of mesoscale properties.

PUBLICATION:

Niiler, P.P. and Paduan, J.D., "Wind-driven Motions in the Northeast Pacific as Measured by Lagrangian Drifters," Journal of Physical Oceanography, Vol 25, No. 11, pp. 2819-2830, November 1995.

OTHER:

Chaired session on this field program at 42nd Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 26-29 September 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Eddies, ocean currents, Lagrangian drifters

SURFACE CURRENTS AND TEMPERATURES FROM DRIFTING BUOY AND SATELLITE ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR) MEASUREMENTS IN THE NORTHEAST ATLANTIC OCEAN

Jeffrey D. Paduan, Assistant Professor
Department of Oceanography
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of this project is to analyze surface currents and temperatures from satellite-tracked drifting buoys in the northeast Atlantic Ocean for mean currents, eddy variability, and the convergence patterns associated with the Azores Front.

SUMMARY: These research efforts focused on the comprehensive analysis of surface current and temperature observations from drifting buoys deployed in the northeast Atlantic Ocean and surface temperatures from satellite-borne AVHRR sensors. The data stems from July 1991 through March 1995 for the region of the Canary Basin south of the Azores Islands. The measurements were sponsored by joint projects of the Office of Naval Research and the French Meteorological Agency termed SUBDUCTION and SEMAPHORE, respectively. A total of 70 U.S. and 25 French drifters were deployed making the region of the Azores Front one of the most highly-sampled in the world. Mesoscale

eddy temperature flux statistics were computed at a resolution of 1 degree latitude x 2 degrees longitude. Weekly estimates of the location of the Azores Front were made based on satellite-derived temperature maps and drifter trajectories and a method was developed to recast velocity observations in a reference frame relative to the front.

PUBLICATION:

Paduan, J.D., Zhou, M., and Niiler, P.P., "Surface Currents in the Canary Basin from Drifter Observations," International WOCE Newsletter, No. 20, pp. 13-15, September 1995.

CONFERENCE PRESENTATION:

Zhou, M., Niiler, P.P., and Paduan, J.D., "Statistical Properties of the Surface Currents in the Canary Basin Observed by SVP drifters," XXI General Assembly of the International Association for the Physical Sciences of the Oceans, Honolulu, HI, 5-12 August 1995.

THESIS DIRECTED:

Brown, J.E.M., "Drifter-based Velocity Statistics in the Vicinity of the Azores Front," Master's Thesis, December 1995.

DOD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Eddies, fronts, ocean currents, Lagrangian drifters

SCIENTIFIC DEVELOPMENT OF A MASSIVELY PARALLEL OCEAN CLIMATE MODEL

Albert J. Semtner, Professor
Department of Oceanography
Sponsor: Department of Energy

OBJECTIVE: To develop detailed models of the global ocean circulation with all relevant physical processes important for prediction, as well as to validate the models against existing observations. To understand the physical processes in the ocean that affect oceanic predictability and climatic fluctuations and change.

SUMMARY: A global ocean model, capable of producing accurate forecasts out to the limits of climate predictability when properly coupled to a valid atmospheric model, has to be well designed and able to run on the advanced supercomputers of the future, which are expected to be of massively parallel design. The present research is moving an eddy- resolving model onto massively parallel computers, for coupled modeling related to CHAMMP. To guide the additional physical development of a comprehensive model, scientific study in three areas is now underway: 1) investigation of the physics of ocean heat transport; 2) inclusion of near-surface oceanic processes relevant to climate; and, 3) examination of resolution requirements for ocean modeling. Last year, high-latitude process improvements and analyses of resolution effects were emphasized. A fully validated model will be available by project completion in 1997.

PUBLICATIONS:

Semtner, A.J., "Very High-resolution Estimates of Global Ocean Circulation, Suitable for Carbon-cycle Modeling," Proceedings of the Snowmass Global Change Institute on the Global Carbon Cycle, Office of Interdisciplinary Earth Studies, Boulder, CO, in press.

Semtner, A.J., "Modeling Ocean Circulation," SCIENCE, Vol. 269, No. 5229, pp.1379-1385, 8 September 1995.

CONFERENCE PRESENTATIONS:

Semtner, A.J., "Recent Global Eddy-Resolving Ocean Simulations and TOPEX Comparisons," Marine Sciences Department, University of Alaska, Fairbanks, 18 April 1995; Non-linear Science Colloquium, Los Alamos National Laboratory, NM, 16 May 1995; IUGG Non-linear Fluids Symposium; Boulder, CO, 5 July 1995; PetaFLOPS Computing Workshop, Bodega Bay, CA, 17 August 1995; Operational Oceanography Symposium, Biarritz, France, 19 October 1995; and Atmospheric Sciences Department, Colorado State University, 30 November 1995.

Semtner, A.J., "High-resolution Results for the Arctic Ocean and Sea Ice, in the Context of Global Modeling," CHAMMP Science Team Meeting in Rockville, MD, 2 October 1995.

THESIS DIRECTED:

Parsons, A.R., LCDR, "On the Barents Sea Polar Front in Summer and Interpretations of the Associated Regional Oceanography Using an Arctic Ocean General Circulation Model," Ph.D. Dissertation, September 1995.

OTHER:

Braccio, P., and Semtner, A.J., "Global Ocean Animations from the Los Alamos POP Model, Emphasizing the Southern Hemisphere," videotape of scientific ocean animations produced at the Naval Postgraduate School, 35 minutes, 1995.

Ramp, S.R., McClean, J.L., Collins, C.A., Semtner, A.J., and Hays, K.A.S., "Observations and Modeling of the 1991-92 El Nino Signal off Central California," submitted to Journal of Geophysical Research, June 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical modeling, ocean prediction, parallel computing

SIMULATIONS AND RECONSTRUCTIONS OF GLOBAL OCEAN CIRCULATION WITH WELL-RESOLVED EDDIES FOR THE WOCE OBSERVATIONAL PERIOD 1991-97

Albert J. Semtner, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The goal is to further improve on the realism of numerical models of global three-dimensional ocean circulation with important currents and eddies resolved, to conduct simulations using the best available atmospheric forcing, and to assimilate satellite altimeter data in certain of the studies. This 5-year project runs until 1999.

SUMMARY: A model had been developed with 1/4 x 2/5 deg lat/lon grid and 20 vertical levels, with proper representation of coastlines and depths. Last year, a number of physical and numerical improvements were made; and high-frequency wind fields and monthly heat fluxes were prepared as forcing. The model was used to simulate conditions of 1987-95, starting from earlier 1985-89 monthly-wind-forced calculations and applying new fields of 3-day winds and heat flux. A massive amount of model output was compared with both in-situ and satellite observations and found to be in excellent agreement with what actually happened. The agreement of predicted surface height variability with that observed by NASA's superb TOPEX satellite altimeter was especially impressive. Since then, satellite data-assimilation efforts have been underway to include the height data from both TOPEX and ERS satellites over the period 1992-95. Early results are showing improvements in the timing and amplitude of current fluctuations, as well as statistical improvements in the mean and variability - all calibrated against actual observations. Higher resolution models are being developed for use in further research.

PUBLICATIONS:

Semtner, A.J., "Very High-resolution Estimates of Global Ocean Circulation, Suitable for Carbon-cycle Modeling," Proceedings of the Snowmass Global Change Institute on the Global Carbon Cycle, Office of Interdisciplinary Earth Studies, Boulder, Co, in press.

Semtner, A.J., "Modeling Ocean Circulation," SCIENCE, Vol. 269, No. 5229, pp.1379-1385, 8 September 1995.

Tokmakian, R.T., and Semtner, A.J., "Mesoscale Global Ocean Circulation Modeling with Assimilation," International WOCE Newsletter, No. 21, pp. 4-7, Southampton, United Kingdom, November 1995.

CONFERENCE PRESENTATIONS:

Semtner, A.J., "Recent Global Eddy-Resolving Ocean Simulations and TOPEX Comparisons," Marine Sciences Department, University of Alaska, Fairbanks, 18 April 1995; Non-linear Science Colloquium, Los Alamos National Laboratory, NM, 16 May 1995; IUGG Non-linear Fluids Symposium; Boulder, CO, 5 July 1995; PetaFLOPS Computing Workshop, Bodega Bay, CA, 17 August 1995; Operational Oceanography Symposium, Biarritz, France, 19 October 1995; and Atmospheric Sciences Department, Colorado State University, 30 November 1995.

THESIS DIRECTED:

Staten, R., LT, "Modeling Acoustic Transmissions between Hawaii and Monterey," Master's Thesis, September 1995.

OTHER:

Stammer, D., Tokmakian, R.T., Semtner, A.J., and Wunsch, C., "How Well Does a 1/4-deg. Global Circulation Model Simulate Large-Scale Observations?," submitted to Journal of Geophysical Research, September 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical modeling, ocean prediction

HIGH-PERFORMANCE MODELING OF THE ARCTIC OCEAN CIRCULATION IN TURBULENT EQUILIBRIUM

Albert Semtner, Professor
Wieslaw Maslowski, Assistant Professor
Department of Oceanography
Sponsor: Cray Research, Inc.

OBJECTIVE: To greatly improve on the realism of numerical simulation of three-dimensional Arctic ocean circulation, with important currents and eddies resolved for the first time ever. To do this by exploiting the power of massively parallel computers, especially the CRAY T3D at the Arctic Region Supercomputing Center in Fairbanks.

SUMMARY: It was proposed to design a high-resolution model of the Arctic Ocean which is optimized to run on the massively parallel CRAY T3D and to simulate the realistic thermohaline circulation of the Arctic Ocean even before it has been adequately observed. This effort will conclusively demonstrate the power of high-performance Cray computers to solve realistic fluid dynamical problems in oceanography. Many scientific and practical applications can then be made with the model. Already, a model with 18-km grid spacing and 32 levels has been built and run for a

major simulation of 25 years. Results for the full Arctic region plus subpolar North Atlantic are looking extremely realistic and are generating much interest and acceptance from polar oceanographers. Analysis of results and the distribution of output in the form of video animations is in progress.

CONFERENCE PRESENTATIONS:

Maslowski, W., "Advanced High-Resolution Arctic Ocean Model," Nordic Seas Symposium, Hamburg, Germany, 7-9 March 1995; Arctic Shelf-Basin Interactions Workshop, Townsend, TN, 23-25 March 1995; Arctic System Science Modeling Workshop, Boulder, CO, 6-8 August 1995; and Cray User Group Conference, Fairbanks, AK, 25-29 September 1995.

THESIS DIRECTED:

Parsons, A.R., LCDR, "On the Barents Sea Polar Front in Summer and Interpretations of the Associated Regional Oceanography using an Arctic Ocean General Circulation Model," September 1995.

OTHER:

Maslowski, W., Parsons, A.R., Zhang, Y., and Semtner, A.J., "High-Resolution Arctic Ocean and Sea Ice Simulations: Model Design and Early Results," submitted to Journal of Geophysical Research, December 1995.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical modeling, Arctic Ocean, parallel computers

MIXED LAYER TURBULENCE MEASUREMENTS DURING THE ANZONE WINTER FLUX EXPERIMENT: ANZFLUX

Timothy P. Stanton, Associate Research Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The objectives of this research are to identify and model physical mechanisms responsible for maintaining anomoulously thin winter ice cover over the central Weddell Sea. As large scale, winter-long polynias intermittently form in this area, the potential exists for massive ocean/atmosphere heat fluxes which can significantly effect the global heat budget and bottom water formation.

SUMMARY: During our participation in the ANZFLUX experiment deployed from the icebreaker N. B. Palmer during July and August 1994, two, one week ice camps were established approximately 500m from the ship on O(30 cm) ice to make direct heat, salt and momentum flux measurements in the ocean mixed layer. Analysis of the continuous profiling microstructure probe, a turbulence-resolving Broad Band Acoustic Doppler Current profiler, and three near-surface *in situ* temperature, salinity and 3 component velocity instrument clusters have allowed the turbulent coupling of the ice/ocean interface to be characterized in the presence of rapidly evolving, very high wind stress events which dominated the weather at the measurement site. The continuous mixed layer and upper pycnocline profile measurements resolved the evolving mixed layer thermohaline structure, turbulent dissipation rates and very small vertical gradients of temperature and salinity, allowing heat fluxes and pycnocline diffusivity timeseries to be estimated.

Preliminary analyses of the mixed layer structure during both ice camps were contributed to an overview paper of the ANZFLUX experiment in press in BAMS. Estimates of heat fluxes during the warm regime measurements were presented in an AJUS article in press. Two single authored papers are in progress. The first describes and models the modulation of turbulent entrainment of the deep pycnocline in response to both the high surface stress events and the

10-50m internal wave and eddy displacements encountered during the observation period. A second paper describes a comparison of stress and turbulent shear production measured by several different methods at the site. These unique comparisons of acoustic doppler measurements of boundary layer turbulence using conventional geometry acoustic doppler profilers show a new application of acoustic doppler current profilers. Two collaborative papers in preparation describe the effects of internal waves on heat fluxes within the pycnocline, and the effects of double diffusion and cabling in the pycnocline.

PUBLICATIONS:

McPhee, M, Ackley, S., Guest, P., Huber, B., Martinson, D., Morison, J., Muench, R., Padman, L., and Stanton, T., "The Antarctic Zone Flux Experiment," Bulletin of American Meteorological Society, in press.

Stanton, T.P., "Mixed Layer Structure and Turbulent Fluxes in the Eastern Weddell Sea during the ANZFLUX Experiment," Antarctic Journal of the United States, 1995.

CONFERENCE PRESENTATIONS:

Stanton, T.P. and Stockel, J., "Evolution of the Ocean Surface Layer in the Weddell Sea in Response to Strong Storm Events," IAPSO Conference, August 1995.

Stanton, T.P., Stockel, J., McPhee, M.G., Padman, L., and Robertson, R., "Turbulent Heat Fluxes Near the Base of the Mixed Layer in the Weddell Sea," IAPSO Conference, August 1995.

OTHER:

Convener of an ANZFLUX workshop in March 1995.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean mixed layer, antarctic ocean fluxes, mixed layer dynamics

INTERNAL WAVE AND TURBULENCE MEASUREMENTS DURING THE COASTAL OCEAN PROCESSES EXPERIMENT (COPE)

Timothy P. Stanton, Associate Research Professor
Department of Oceanography
Sponsors: National Oceanographic and Atmospheric Agency (NOAA) and Office of Naval Research

OBJECTIVE: The objectives of this research were to define the surface strain and internal mixing effects of high displacement, near-surface internal soliton packets over the continental shelf.

SUMMARY: In October 1995, the principal investigator participated in the NOAA ETL sponsored Coastal Ocean Processes Experiment (COPE) by deploying three instrument systems from R/P FLIP for a three week period, 20Km off shore of Northern Oregon. A continuous profiling loose-tethered microstructure profiler measured high resolution temperature, salinity and dissipation profiles every 40 seconds from the surface to a depth of 35m. A rigid instrument frame suspended from one of FLIP's booms was equipped with five *in situ* temperature, salinity and 3 component velocity instrument clusters which spanned 3 to 8m depth, while a high speed broadband ADCP extended the velocity and stress measurements to 50m depth.

The measurement site had a 60 cph pycnocline at only 5 - 10m depth, allowing the existence of extremely nonlinear soliton packets which were consistently observed on the leading edge of the seimidiurnal internal tide displacements. The soliton packets had downward isopycnal displacements of up to 30m from a 5m depth, significantly more non-linear than previous observations.

OTHER:

A conference presentation has been prepared for the February 1996 Ocean Sciences meeting in San Diego and a manuscript is being prepared in collaboration with Lev Ostovsky at the NOAA ETL for submission to "Science."

Isotherm and isopycnal displacements forwarded to the ETL COPE data base.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean mixed layer, internal waves, mixed layer dynamics

OCEAN MIXED LAYER PROCESSES DURING THE IRON ENRICHMENT EXPERIMENT

Timothy P. Stanton, Associate Research Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The primary objective of this research is to identify and model the physical processes which contribute to the horizontal and vertical diffusion of areas of open ocean which have had chemical tracers introduced at the surface. A secondary objective was to design and implement a system to permit open ocean seeding and sampling experiments to be performed even in the presence of strong horizontal advection and inertial motions.

SUMMARY: During participation in the Iron Enrichment Experiment in October 1993, three observation systems were used to measure the atmospheric forcing, mixed layer current response and three dimensional mixed layer structure in the experiment area. A Lagrangian reference frame was established to navigate the presurvey, iron-enrichment phase, and ten day patch evolution survey period by deploying a telemetered, GPS navigated buoy in the center of the measurement domain, 300 km south of the Galapagos Island. Real-time analysis methods allowed daily maps of the evolving physical, chemical and biological properties to be made. After three days, primary productivity had tripled in the 10 km square iron enriched area, producing a signature observable from concurrent NASA remote sensing flights.

The use of the conserved chemical tracer, SF_6, mixed with the trace iron provided a unique opportunity to measure and model the horizontal and vertical diffusion of the surface injected tracer patch in open ocean conditions. The results of the physical analyses of the mixed layer processes contributing to the diffusion are the subject of two submitted publications, and third nearing completion.

CONFERENCE PRESENTATION:

Stanton, T.P., "Mixed Layer Dispersion of a Mesoscale Surface Patch During the Galapagos Iron Enrichment Experiment," XXI IAPSO Abstracts, p. 176, 1995.

OTHER:

Stanton, T.P., Law, C.S., and Watson, A.J., "Physical Evolution of the IRONEX-I Open Ocean Tracer Patch," submitted to Deep Sea Research.

Law, C.S., Watson, A.J., Liddicoat, M.I., and Stanton, T.P., "Sulphur Hexafluoride as a Tracer os Biogeochemical and Physical Processes in an Open Iron Fertilization Experiment," submitted to Deep Sea Research.

Stanton, T.P. and Watson, A.J., "Horizontal Diffusion Processes in Open Ocean Mixed Layers," to be submitted to Journal of Physical Oceanography.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Tracer dispersion, ocean mixed layer, ocean mixing

NEAR SHORE WAVE PROCESSES

Edward B. Thornton, Professor
Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore given the offshore wave conditions.

SUMMARY: The longshore currents maximum observed in the trough of the barred beach during DELILAH is not predicted by present theory. The simplest longshore current models balance cross-shore changes in the alongshore wave momentum (radiation stress) with the alongshore bottom shear stress. Waves break over the bar, reform in the trough and again break on the foreshore. Wave breaking results in changes in the radiation stress predicting two jets, one over the bar and one at the foreshore, which does not agree with the observed current maximum in the trough. A number of mechanisms have been investigated, which are described in a series of papers to explain the observed longshore currents.

Church, Thornton, and Oltman-Shay (1995) show shear instabilities of longshore currents to be a significant momentum mixing mechanism resulting in the modification of the longshore current profile. Cross-shore profiles of the integrated Reynolds' stresses are calculated using model generated stream functions whose amplitudes are calibrated via observed energy density spectra using data from the DELILAH experiment. The mixing predicted due to shear instabilities is found to be in qualitative agreement with that required for modeled longshore current profiles to agree with observed profiles for the barred beach studied.

Lippmann and Thornton (1995) used wave roller theory in an energy balance model to predict the cross-shore spatial distribution of rollers and the associated surface shear stress exerted by the shoreward advection of rollers on the underlying water column. Production of turbulence at the wave/roller interface occurs through the shear stress exerted by the roller on the water column. The roller model is found to depend on the ratio f/e where f is the wave frequency and e is a measure of the asymmetry of the wave form. The model is indirectly evaluated using percentages of wave breaking obtained from video measurements. For long crested, narrow banded incident waves during the 1990 DELILAH experiment, the percentages of wave rollers predicted by the model gives an excellent fit to field measurements.

Reniers and Thornton (1995) show that even for the seemingly alongshore uniform bathymetry during DELIlAH, small variations create alongshore pressure gradients of first order importance. Using scaling argument, they show that for small alongshore changes in bathymetry, a quasi-3D dynamics model is appropriate. The cross-shore set-up is first calculated at various alongshore locations from which the alongshore pressure gradient forcing is calculated, and shown to be a dominate forcing mechanism in the trough where changes in radiation stress are a minimum. These results point to the need to measure alongshore pressure gradients during the SandyDuck experiment.

Thornton, Soares and Stanton (1995) show the vertical profile of longshore current measured with a vertical array of 8 electromagnetic current meters is well described by a logarithmic profile for strong longshore current days (Figure 2) during Duck94 (0.98 mean linear correlation coefficient for all profiles). Equating the bottom shear stress determined from the log profile with a quadratic bed shear stress formulation, bed shear stress coefficients, Cf, were calculated. Measured Cf values varied by an order of magnitude across the surf zone. The Cf values were found proportional to the measured rms bed roughness, R, as measured by a sonic altimeter and bed form type identified by a side-scan sonar mounted on the CRAB.

PUBLICATIONS:

Dickson, W.S., Herbers, T.H.C., and Thornton, E.B., "Wave Reflection from a Breakwater," Journal of Waterways, Port, Coastal and Ocean Engineering, Vol. 121, No. 5, pp. 262-268, 1995.

Whitford, D.J. and Thornton, E.B., "Bed Shear Stress Coefficients for Longshore Currents over a Barred Beach," Journal of Coastal Engineering, in press.

Lippmann, T., Thornton, E.B., and Brookins, H., "Breaking Wave Transformation using a Roller Model," Journal of Coastal Engineering, in press.

Thornton, E.B., Humiston, R.T., and Birkemeier, W., "Bar/Trough Generation on a Natural Beach," Journal of Geophysical Research, in press.

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilites of the Longshore Current," Proceedings of Coastal Dynamics '94, pp. 376-390, 1995.

Birkemeier, W.A. and Thornton, E.B., "The Duck94 Nearshore Field Experiment," Proceedings of Coastal Dynamics '94, pp. 815-821, 1995.

Garcez Faria, A.F., Thornton, E.B., and Stanton, T.P., "A Quasi-3D Model of Longshore Currents," Coastal Dynamics '95, 1995.

Thornton, E.B., Soares, C., and Stanton, T.P., "Vertical Profile of Mean Longshore Currents and Bed Shear Stress," Coastal Dynamics '95, 1995.

Lippmann, T.C. and Thornton, E.B., "Wave Stress and Longshore Currents on Barred Profiles," Coastal Dynamics '95, 1995.

Reniers, A. and Thornton, E.B., "Longshore Currents over Barred Beaches," Coastal Dynamics '95, 1995.

Kohanowich, K.M., Stanton, T.P., and Thornton, E.B., "Acoustic Sediment Flux Measurements from DUCK '94," Coastal Dynamics '95, 1995.

CONFERENCE PRESENTATIONS:

Thornton, E.B., Stanton, T., and Garcez Faria, A., "Bottom Shear Stresses Derived from Mean Longshore Current Profiles during Duck '94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Garcez Faria, A., Thornton, E., and Stanton, T., "Cross-shore Mean Flow during Mean Flow during Duck '94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Jorgensen, C., Lippmann, T., and Thornton, E., "Observations of Wave Slopes and Breaking Distributions in the Surf Zone," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Thornton, E.B., "Surf Zone Environment," Mines and Mine Countermeasures Conference, Naval Postgraduate School, Monterey, CA, 4-7 April 1995.

Thornton, E.B., "Breaking Waves within the Surf Zone and Wave-induced Dynamics," Army/Navy Wave Prediction Group Workshop, Naval Research Lab, Monterey, CA, 10 February 1995.

THESES DIRECTED:

Faria, A., "Quasi-3D Nearhore Circulation Model," Master's Thesis, 1995.

Kohanowich, K.M., "Calibration of a Coherent Acoustic Sediment Profiler (CASP) and Analysis of Sediment Distribution from Duck '94," Master's Thesis, 1995.

McIntyre, T., "Ultrsonic Descrimination of Bubbles and Sediment," Master's Thesis, 1995.

Soares, C., "Vertical Profiles of Longshore Currents," Master's Thesis, 1995.

OTHER:

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilities of the Longshore Current," submitted to Journal of Geophysical Research.

Lippmann, T. and Thornton, E.B., "The Spatial Distribution of Wave Rollers and Turbulent Kinetic Energy on a Barred Beach," submitted to the Journal of Geophysical Research.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Nearshore, waves, surf

WAVE SURFACE AND BOTTOM BOUNDARY LAYERS IN THE NEARSHORE

Edward B. Thornton, Professor
Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objectives of this research are to examine the dynamics of the water column in over the continental shelf and nearshore, regions where forcing is dominated by surface gravity waves and wind. Unique acoustic doppler instruments will be used to look at a boundary layer turbulent properties.

SUMMARY: Progress on the objectives of this research were focused on development of a Bistatic geometry, coherent acoustic Doppler Velocity profiler (BCDV) with can make cm resolution, three component velocity measurements out to a range of 1.5m. The profiler has been laboratory tested in preparation for a filed deployment in May 1996. The profiler will be used to determine turbulent stress profiles from the sediment bed to 1m height in the strongly oscillatory boundary layer found in the nearshore.

Measurements of directional wave spectra, near-surface dissipation stress were made as a component of the COPE field program deployed from FLIP in October 1995. This three week long timeseries covered wave heights from 0.5m to 3m, and winds up to $18ms^{-1}$. Analyses of these unique timeseries are directed at studying wave induced turbulence in the upper ocean, where an order of magnitude increase in dissipation rates over "law of the wall" models have been predicted.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Waves

SURF AND NEARSHORE CURRENT PREDICTION

Edward B. Thornton, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Develop models to predict the evolution of waves across the surf zone, the currents in the nearshore due to waves, wind and tidal influences, and the changes in the bathymetry, and apply these models to improve the predictive capability of the U.S. Navy Tactical Environmental Support System (TESS) Surf Model.

SUMMARY: Surf prediction models are tested, validated and improved utilizing wave and longshore current data acquired during large -scale field experiments. These experiments include NSTS at Torrey Pines and Santa Barbara, California, and a series of experiments (SUPERDUCK, DELILAH and DUCK94) held at the U.S. Army Field Research Facility in Duck, North Carolina. These combined data provide a wide range of wave conditions from the long period, low steepness Pacific swell to steeper Atlantic storm waves. The experiments were conducted over various bottom profiles including both near-planar and barred beaches.

The wave transformation model has been rederived to include the effects of a surface roller describing breaking waves and dissipation (Lippmann, et al, 1994). resulting formulation also has two parameters to be specified, the steepness of the breaking wave face, S, and the ratio of rms wave height to local depth, B. The model was run for various cases of near planar (Torrey Pines and Santa Barbara) and barred (DELILAH) profiles. It was found that the model is insensitive to S, and moderate to weakly sensitive to B. The average rms error between observed and calculated wave heights for all runs is less than 7%. The modifications result in a single parameter (B) model, with the functional relationship of B weakly constrained by bottom slope.

By modeling the breaking process, predictions of wave energy gradients can be made, allowing estimation of mean cross-shore and alongshore currents. Although this modeling has worked well on plane beaches, data and models do not always agree on barred profiles where there often are large currents in the trough of the bar. One mechanism to account for the momentum deficit has been suggested (Roelvink and Stive, 1989) to be associated with a lag in the dissipation of turbulent energy from its genesis. In this work (Lippmann and Thornton, 1994) the affect of wave rollers on the spatial distribution of turbulent kinetic energy (TKE) was investigated across a naturally barred profile. The model is formulated from the energy flux balance, in which the total energy of the waves is separated into wave and roller components after Svendsen (1984). The energy loss of the roller is formulated following Deigaard (1993), where the total energy balance in the roller is due to the exchange of water across the wave/roller interface. Production of turbulence at the wave/roller interface occurs through the shear stress exerted by the roller on the water column. The roller area is described by the model of Engelund (1981), with slight modification to allow for variable characteristics of the roller geometry. The roller model is found to depend on the ratio f/e where f is the wave frequency and e is a measure of the asymmetry of the wave form. It is found that the horizontal propagation scales depend on e. Since there are no known appropriate measurements of TKE in the surf zone, the model is indirectly evaluated using percentages of wave breaking obtained from video measurements. For long crested, narrow banded incident waves during the 1990 DELILAH experiment, the percentages of wave rollers predicted by the model gives an excellent fit to field measurements.

PUBLICATIONS:

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilities of the Longshore Current," Coastal Dynamic '94, ASCE, pp. 376-390, 1995.

Lippmann, T., Brookins, H., and Thornton, E.B., "Breaking Wave Transformation Using a Roller Model," Journal of Coastal Engineering, in press.

Lippmann, T.C. and Thornton, E.B., "The Spatial Distribution of Wave Rollers and Turbulent Kinetic Energy on a Barred Beach," accepted by Journal of Geophysical Research.

CONFERENCE PRESENTATIONS:

Garcez Faria, A., Thornton, E. and Stanton, T., "Cross-shore Mean Flow during Mean Flow during Duck '94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Jorgensen, C., Lippmann, T., and Thornton, E., "Observations of Wave Slopes and Breaking Distributions in the Surf Zone," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Garcez Faria, A.F., Thornton, E.B., and Stanton, T.P., "A Quasi-3D Model of Longshore Currents," Coastal Dynamics '95, 1995.

Lippmann, T.C. and Thornton, E.B., "Wave Stress and Longshore Currents on Barred Profiles," Coastal Dynamics '95, 1995.

Reniers, A. and Thornton, E.B., "Longshore Currents over Barred Beaches," Coastal Dynamics '95, 1995

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Nearshore, waves, surf

NEARSHORE CIRCULATION ON VARIABLE BATHYMETRY

Edward B. Thornton, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Develop models to predict the evolution of waves and currents in the nearshore due to waves, wind and tidal influences, and the changes in the bathymetry.

SUMMARY: Data previously acquired during the NSTS and Duck field experiments are being processes and made available for this study. The NSTS data were acquired on near-planar beaches at Torrey Pines (1978) and Santa Barbara (1980) California, while the Duck, North Carolina data were acquired on a barred beach in a series of experiments, Duck85, SUPERDUCK (1986), DELILAH (1990) and DUCK94. The data are of a dense cross-shore array or wave and velocity sensors, alongshore array(s) of velocity sensors, direction wave array(s) offshore and well-measure bathymetry. Data will focus on when the bathymetry was 3-D.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Waves, near-shore, edge-waves

1995

Faculty Publications and Presentations

OCEANOGRAPHY

JOURNAL PAPERS

Batteen, M.L., Hu, C.-P., Bacon, J.L., and Nelson, C.S., "A Numerical Study of the Effects of Wind Forcing on the Chile Current System," Journal of Oceanography, Vol. 51, pp. 585-614, 1995.

Batteen, M.L., Collins, C.A., Gunderson, C.R., and Nelson, C.S., "The Effect of Salinity on Density in the California Current System," Journal of Geophysical Research-Oceans, Vol. 100, No. C5, pp. 8733-8749, 1995.

Chiu, C.-S., Miller, J.H., and Denner, W.W., "Modeling of Backscatter and Barrier Sonar System Concepts using a Coupled Normal-Mode Approach (U)," Journal of Underwater Acoustics, pp. 103-116, 1995.

Chu, P.C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," Journal of the Marine Technology Society, Vol. 29, No. 2, pp. 3-14, 1995.

Dickson, W.S., Herbers, T.H.C., and Thornton, E.B., "Wave Reflection from a Breakwater," Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 121, No. 5, pp. 262-268, 1995.

Elgar, S., Herbers, T.H.C., Chandran, V., and Guza, R.T., "Higher-order Spectral Analysis of Nonlinear Ocean Surface Gravity Waves," Journal of Geophysical Research, Vol. 100, No. C3, pp. 4977-4983, 1995.

Herbers, T.H.C., Elgar, S., Guza, R.T., and O'Reilly, W.C., "Infragravity-frequency (0.005-0.05 Hz) Motions on the Shelf, Part II: Free Waves," Journal of Physical Oceanography, Vol. 25, No. 6, pp. 1063-1079, 1995.

Herbers, T.H.C., Elgar, S., and Guza, R. T., "Generation and Propagation of Infragravity Waves," Journal of Geophysical Research, Vol. 100, No. C12, pp. 24863-24872, 1995.

Jiang, L. and Garwood, R.W., "A Numerical Study of Three-dimensional Bottom Plumes on a Southern Ocean Continental Slope," Journal of Geophysical Research, Vol. 111, No. C9, pp. 18471-18488, 1995.

Ly, L. N., "A Numerical Coupled Model for Studying Air-Sea-Wave Interaction," Journal of Physics of Fluid, Vol. 7, No. 10, pp. 2396-2406, 1995.

McClean, J.L. and Klinck, J.M., "Description and Vorticity Analysis of 50-day Oscillations in the Western Tropical Region of the CME Model," Journal of Physical Oceanography, Vol. 25, No. 11, Part 1, pp. 2498-2517, 1995.

Niiler, P.P. and Paduan, J.D., "Wind-driven Motions in the Northeast Pacific as Measured by Lagrangian Drifters," Journal of Physical Oceanography, Vol 25, No. 11, pp. 2819-2830, November 1995.

Paduan, J.D., Zhou, M., and Niiler, P.P., "Surface Currents in the Canary Basin from Drifter Observations," International WOCE Newsletter, No. 20, pp. 13-15, September 1995.

Semtner, A.J., "Modeling Ocean Circulation," SCIENCE, Vol. 269, No. 5229, pp.1379-1385, 8 September 1995.

Stanton, T.P., "Mixed Layer Structure and Turbulent Fluxes in the Eastern Weddell Sea During the ANZFLUX Experiment," Antarctic Journal of the United States, 1995.

CONFERENCE PAPERS

Batteen, M.L. and Braccio, P.G., "Wind-Forced Modeling Studies of the California Current System," Abstracts from the Eastern Pacific Ocean Conference, p. 6, 1995.

OCEANOGRAPHY

Batteen, M.L. and Braccio, P.G., "Modeling Studies of Eastern Boundary Coastal Circulations: A Comparison of the California and Leeuwin Current Systems," XXI International Association for the Physical Sciences of the Oceans (IAPSO) Abstracts, PS-04.508, p. 9, 1995.

Birkemeier, W.A. and Thornton, E.B., "The Duck94 Nearshore Field Experiment," Proceedings of Coastal Dynamics '94, pp. 815-821, 1995.

Chiu, C.-S., Miller, J.H, Denner, W.W., and Lynch, J.F., "A Three-Dimensional, Broadband, Coupled Normal-Mode Sound Propagation Modeling Approach," Full Field Inversion Methods in Ocean and Seismic Acoustics (O. Diachok, A. Caiti, P. Gerstoft and H. Schmidt editors), Kluwer Academic Publishers, pp. 57-62, 1995.

Chiu, C.-S., Miller, J.H., Denner, W.W., and Lynch, J.F., "Forward Modeling of the Barents Sea Tomography Vertical Line Array Data and Inversion Highlights," Full Field Inversion Methods in Ocean and Seismic Acoustics (O. Diachok, A. Caiti, P. Gerstoft and H. Schmidt editors), Kluwer Academic Publishers, pp. 237-242, 1995.

Church, J.C., Thornton, E.B., and Oltman-Shay, J., "Mixing by Shear Instabilites of the Longshore Current," Proceedings of Coastal Dynamics '94, pp. 376-390, 1995.

Garcez Faria, A.F., Thornton, E.B., and Stanton, T.P., "A Quasi-3D Model of Longshore Currents," Coastal Dynamics '95, 1995.

Garwood, R.W., Jr. and Harcourt, R., "The Polar Seas: A Laboratory For Deep Ocean Convection," invited talk, XXII IAPSO Proceedings Abstracts, p. 154, Honolulu, HI, 5-12 August 1995.

Guest, A. and Garwood, R.W., Jr., "Parameterization Of The Equatorial Entrainment Zone," XXII IAPSO Proceedings Abstracts, p. 229, Honolulu, HI, 5-12 August 1995.

Kohanowich, K.M., Stanton, T.P., and Thornton, E.B., "Acoustic Sediment Flux Measurements from DUCK'94," Coastal Dynamics '95, 1995.

Lippmann, T.C. and Thornton, E.B., "Wave Stress and Longshore Currents on Barred Profiles," Coastal Dynamics '95, 1995.

Ly, L.N and Luong, P., "Application of Grid Generation Techniques to the Yellow Sea Simulation," High Performance Computing and Communication (HPC-ASIA 1995), Electronic Proceedings, Taipei, Taiwan, 1995.

Ly, L.N. and Jiang, L., "On the Pressure Gradient Error in the Monterey Bay Sigma Coordinate Ocean Model," American Geophysical Union (AGU), San Francisco, CA, Transactions, O42B-4, No. 45, 1995.

Luong, P. and Ly, L. N., "Application of the Multi-block Grid Technique in Coastal Ocean Modeling: the Mediterranean Simulation," AGU, San Francisco, CA. Transactions, O42B-9, No. 45, 1995.

Ly, L.N. and Tran, V., "A Sensitivity Study of Numerical Solutions of the South China Sea Ocean Model to Various Grids," AGU, San Francisco, CA. Transactions, O41B-2, No. 45, 1995.

Ly, L.N. "High Performance Computing in Coastal Ocean Modeling," Taipei, Taiwan, 1995.

Ly, L.N, Luong, P., O'Connor, W.P., Ezer T. and Mellor, G.L., "A Numerical Study of Circulation and M2 Tide in the Yellow Sea," European Geophysical Society, XX General Assembly, Hamburg, Germany, 1995.

Paduan, J.D., Petruncio, E.T., Barrick, D.E., and Lipa, B.J., "Surface Currents within and offshore of Monterey Bay as Mapped by a Multiple-site HF Radar (CODAR) Network," Proceedings of the IEEE Fifth Working Conference on Current Measurement, pp. 137-142, St. Petersburg, FL, 7-9 February 1995.

Reniers, A. and Thornton, E.B., "Longshore Currents over barred Beaches, Coastal Dynamics '95, 1995.

Stanton, T.P., "Mixed Layer Dispersion of a Mesoscale Surface Patch during the Galapagos Iron Enrichment Experiment," XXI IAPSO Abstracts, p. 176, August 1995.

Stanton, T.P. and Stockel, J., "Evolution of the Ocean Surface Layer in the Weddell Sea in Response to Strong Storm Events," XXI IAPSO Abstracts, p. 149, August 1995.

Stanton, T.P., Stockel, J., McPhee, M.G., Padman, L., and Robertson, R., "Turbulent Heat Fluxes Near the Base of the Mixed Layer in the Weddell Sea," XXI IAPSO Abstracts, p. 149, August 1995.

Thornton, E.B., Soares, C., and Stanton, T.P., "Vertical Profile of Mean Longshore Currents and Bed Shear Stress," Coastal Dynamics '95, 1995.

CONFERENCE PRESENTATIONS

Batteen, M.L. and Braccio, P.G., "Modeling Studies of Eastern Boundary Coastal Circulations: A Comparison of the California and Leeuwin Current Systems," XXI International Association for the Physical Sciences of the Oceans, Honolulu, Hawaii, HI, August 1995.

Batteen, M.L. and Braccio, P.G., "Wind-Forced Modeling Studies of the California Current System," Eastern Pacific Ocean Conference, Stanford Sierra Camp, Fallen Leaf, CA, September 1995.

Chiu, C.-S., "Simulation Results of Acoustic Mode Propagation and Filtering Pertaining to PRIMER Tomography," 1st PRIMER Workshop, Woods Hole, 17 October 1995.

Chu, P.C. and Lozano, C., "P-vector Method for Determining Absolute Velocity from Hydrographic Data," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Lozano, C., and Fan, C.W., "A Regularized Inverse for Beta-spiral Dynamics," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Chu, P.C., Fan, C.W., and Lozano, C.J., "P-vector Method for Assimilating Hydrographic Data into Ocean Circulation Models," American Geophysical Union Fall Meeting, San Francisco, CA, 12-16 December 1995.

Chu, P.C., Wells, S., Haeger, S., Szczechowski, C., and Carron, M., "Spatial and Temporal Decorrelation Scales of the Yellow Sea Thermal Fields," International Liege Colloquium on Dynamics of the Regions of Fresh Water Influence, Liege, Belgium, 8-13 May 1995.

Chu, P.C., Fralick, C., Haeger, S., and Carron, M., "A Feature Model for the Continental Shelf Thermal Structure," International Liege Colloquium on Dynamics of the Regions of Fresh Water Influence, Liege, Belgium, 8-13 May 1995.

Chu, P.C. and Chang, C.P., "A Case Study of the South China Sea Warm Pool," International CLIVA-GOALS Workshop on Asian-Australian Monsoon Oceanography and Meteorology, Melbourne, Australia, 10-12 April 1995.

Chu, P.C. and Chang, C.P., "Feedback between South China Warm Pool and Asian Monsoon Onset," International Symposium on Climate Variability and Predictability, Melbourne, Australia, 10-12 April 1995.

Chu, P.C. and Chang, C.P., "South China Sea Warm Pool and Monsoon Development," invited, International South China Sea Monsoon Experiment (SCSMEX) Scientific Workshop, Beijing, China, 5-7 June 1995.

Chu, P.C., "The South China Sea Prediction System," invited, ONR Naval Ocean Modeling and Prediction (NOMP) Workshop, Stennis Space Center, MI, 21-22 March 1995.

Chu, P.C., "The Environmental Prediction Systems for the Joint Warfare Analysis," invited speaker, Weather Impact and Decision Aid (WIDA) Conference, organized by the Air Force Phillips Lab, NRAD, San Diego, CA, 28-29 March 1995.

Chu, P.C., "A Feature Model for Arctic Upper Ocean Thermal Structure," the American Meteorological Society Annual Meeting, Dallas, TX, 9-13 January 1995.

Chu, P.C. and Bourke, R.H., "The Beaufort Sea Thermal Variabilities Detected from the Navy's MOODS Data," The SHEBA Ocean/Ice Working Group Meeting, Seattle, WA, 9-10 November 1995.

Chu, P.C., "Joint Warfare Environmental Prediction Systems," invited, The Sixty-Third Military Operations Research Society (MORS) Symposium, Annapolis, MD, 7 June 1995.

Chu, P.C., "Inverse Methods" and "Localized Spectral Analysis," invited, Naval Research Lab, Stennis Space Center, MI, 26 October 1995; invited Institut Fur Meereskunde, Kiel, Germany, 18 May 1995; LODYC, University of Paris 6, France, 22 May 1995; and, James Rennel Research Center for Ocean Circulation, Southampton, U.K., 24 May 1995.

Chu, P.C., "P-Vector Inverse Method for Determining North Atlantic Ocean Circulation," invited, James Scripps Oceanographic Institution, University of California at San Diego, CA, 20 September 1995.

Chu, P.C., "S Transform for Obtain Localized Spectra," invited, NASA/JPL, Pasadena, CA, 21 September 1995.

Elgar, S., Guza, R.T., Raubenheimer, B., Herbers, T.H.C., and Gallagher, E., "Observations of Wave Evolution during Duck94," American Geophysical Union Fall Meeting, San Francisco, CA, 1-15 December 1995.

Evangelidis, D., Herbers, T.H.C., Jessen, P.F., Elgar, S., O'Reilly, W.C., and Guza, R. T., "Wave Propagation across the Continental Shelf. 2. Infragravity Waves," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Feddersen, F., Guza, R.T., Elgar, S., and Herbers, T.H.C., "Observations of Nearshore Currents in Duck94," Coastal Dynamics '95: An International Conference on the Role of Large Scale Experiments in Coastal Research, Gdansk, Poland, 4-8 September 1995.

Feddersen, F., Guza, R.T., Elgar, S., and Herbers, T.H.C., "Observations of Longshore Current in Duck94/CooP," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Garcez Faria, A., Thornton, E.B., and Stanton, T.P., "Cross-shore Mean Flow during Duck94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Garcez Faria, A.F., Thornton, E.B., and Stanton, T.P., "A Quasi-3D Model of Longshore Currents," Coastal Dynamics '95, 1995.

Garfield, N. and Collins, C.A., "Subsurface Velocity and Transport Measurements Off Central California," EPOC, Fallen Leaf Lake, CA, September 1995.

Garwood, R.W., Jr. and Harcourt, R., "The Polar Seas: A Laboratory For Deep Ocean Convection," invited talk, XXII IAPSO Proceedings Abstracts, p. 154, Honolulu, HI, 5-12 August 1995.

Garwood, R.W., Jr. and Harcourt, R., "Response Of Deep Ocean Convection To Transient Forcing," invited talk, ONR Labrador Sea Workshop, Washington, DC, 30 October - 1 November 1995.

Guest, A. and Garwood, R.W., Jr., "Parameterization Of The Equatorial Entrainment Zone," XXII IAPSO Proceedings Abstracts, p. 229, Honolulu, HI, 5-12 August 1995.

Hendrickson, E. J., Herbers, T.H.C., Jessen, P.F., O'Reilly, W.C., and Elgar, S., "Wave Propagation across the Continental Shelf. 1. Swell," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Herbers, T.H.C., Burton, M.C., Elgar, S., and Guza, R.T., "Directional Spreading Effects on Shoaling Waves," Coastal Dynamics '95: An International Conference on the Role of Large Scale Experiments in Coastal Research, Gdansk, Poland, 4-8 September 1995.

Jorgensen, C., Lippmann, T., and Thornton, E., "Observations of Wave Slopes and Breaking Distributions in the Surf Zone," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Lippmann, T.C. and Thornton, E.B., "Wave Stress and Longshore Currents on Barred Profiles," Coastal Dynamics '95, 1995.

Lozano, C. and Chu, P.C., "Ocean Circulation Analysis with Three Conserved Variables," 21st General Assembly of the International Association for the Physical Sciences of the Oceans (IAPSO), Honolulu, HI, 5-12 August 1995.

Ly, L.N, and Jiang, L., "On the Pressure Gradient Error in the Monterey Bay Sigma Coordinate Ocean Model," American Geophysical Union Fall Meeting, San Francisco, CA, December 1995.

Lynch, J.F., Jin, G., Traykovski, P., Chiu, C.-S., and Miller, J.H., "Scattering of Acoustic Tomographic Signals in Shallow Water by Internal Waves," 129th Meeting of the Acoustical Society of America, Washington, DC, 30 May - 3 June 1995.

Maslowski, W., "Advanced High-Resolution Arctic Ocean Model," Nordic Seas Symposium; Hamburg, Germany; 7-9 March; Arctic Shelf-Basin Interactions Workshop, Townsend, TN, 23-25 March; Arctic System Science Modeling Workshop, Boulder, CO, 6-8 August; Cray User Group Conference, Fairbanks, AK, 25-29 September 1995.

McClean, J.L., "Comparisons of Global Statistics from the Semtner and Chervin Quarter-degree and the Los Alamos Sixth-degree Models and Altimeter Data," Oceanography Department seminar series, Naval Postgraduate School, Monterey, CA, January 1995.

McClean, J.L., Ramp, S.R., and Semtner, A.J., "Modeling of the 1991-1992 El Nino off Central California," Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, September 1995.

Paduan, J.D., Petruncio, E.T., Barrick, D.E., and Lipa, B.J., "Surface Currents within and offshore of Monterey Bay as Mapped by a Multiple-site HF Radar (CODAR) Network," IEEE Fifth Working Conference on Current Measurement, St. Petersburg, FL, 7-9 February 1995.

Paduan, J.D., Rosenfeld, L.K., Cook, M.S., and Anderson, T., "Remotely Sensed Surface Currents in Monterey Bay from Shore-based HF Radar (CODAR)," 42nd Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 26-29 September 1995.

Petruncio, E.T., Rosenfeld, L.D., and Paduan, J.D., "Observations and Modeling of Tidal Currents in a Submarine Canyon," 42nd Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 26-29 September 1995.

Reniers, A. and Thornton, E.B., "Longshore Currents over Barred Beaches," Coastal Dynamics '95, 1995.

Semtner, A., "Recent Global Eddy-Resolving Ocean Simulations and TOPEX Comparisons," Marine Sciences Department, University of Alaska, Fairbanks, AK, 18 April 1995; Non-linear Science Colloquium, Los Alamos National Laboratory, 16 May 1995; IUGG Non-linear Fluids Symposium, Boulder, CO, 5 July 1995; PetaFLOPS Computing Workshop, Bodega Bay, CA, 17 August 1995; Operational Oceanography Symposium, Biarritz, France, 19 October 1995; Atmospheric Sciences Department, Colorado State University, 30 November 1995.

Semtner, A., "High-resolution Results for the Arctic Ocean and Sea Ice, in the Context of Global Modeling" CHAMMP Science Team Meeting in Rockville, MD , 2 October 1995.

Stanton, T.P. and Stockel, J., "Evolution of the Ocean Surface Layer in the Weddell Sea in Response to Strong Storm Events," IAPSO Conference, August 1995.

Stanton, T.P., Stockel, J., McPhee, M.G., Padman, L., and Robertson, R., "Turbulent Heat Fluxes Near the Base of the Mixed Layer in the Weddell Sea," IAPSO Conference, August 1995.

Staten, R.A. and Chiu, C.-S., "A Simulation Study of the Variability of Acoustic Transmissions from Hawaii to Monterey," 2nd International Conference on Theoretical and Computational Acoustics, Honolulu, HI, 21-25 August 1995.

Thornton, E.B., "Surf Zone Environment," Mines and Mine Countermeasures Conference, Naval Postgraduate School, Monterey, CA, 4-7 April 1995.

Thornton, E.B., "Breaking Waves within the Surf Zone and Wave-induced Dynamics," Army/Navy Wave Prediction Group Workshop, Naval Research Laboratory, Monterey, CA, 10 February 1995.

Thornton, E.B., Stanton, T.P., and Garcez Faria, A., "Bottom Shear Stresses Derived from Mean Longshore Current Profiles during Duck94," American Geophysical Union Fall Meeting, San Francisco, CA, 11-15 December 1995.

Tokmakian, R.T. and Semtner, A.J., "Mesoscale Global Ocean Circulation Modeling with Assimilation," International WOCE Newsletter, No. 21, pp. 4-7, Southampton, United Kingdom, November 1995.

Zhou, M., Niiler, P.P., and Paduan, J.D., "Statistical Properties of the Surface Currents in the Canary Basin Observed by SVP Drifters," XXI General Assembly of the International Association for the Physical Sciences of the Oceans, Honolulu, HI, 5-12 August 1995.

CONTRIBUTIONS TO BOOKS

Chu, P.C., "A Feature Model for the Arctic Upper Ocean Thermal Structure," Polar Meteorology and Oceanography, Vol. 4, pp. 224-227, 1995.

OCEANOGRAPHY

TECHNICAL REPORTS

Batteen, M.L., "Process-Oriented Modeling Studies of Wind Forcing Effects on the California Current System," Research Activities in Atmospheric and Oceanic Modeling, A. Staniforth (ed.), CAS/JSC Working Group on Numerical Experimentation, Vol. 21, 8.7, 1995.

Garfield, N., Collins, C.A., Rago, T.A., Mascarenhas, A., and Devora, A.S., "Pegasus in the Sea of Cortes Area (PESCAR): Pegasus Data Report for PESCAR Cruises in April and December 1992," Naval Postgraduate School Technical Report, NPS-OC-95-001, 81 pp., 1995

Miller J.H., Benson, J.L., Chiu, C.-S., and Greineder, S., "Localization of Submarine Transients in Shallow Water (U)," Naval Postgraduate School Technical Report, NPS-UW-95-001, January 1995. (S-NF)

Sagavoc,C.P., Danielson, D.A., Clynch, J.R., and Neta, B., "Fast Interpolation for Global Positioning System (GPS) Satellite Orbits," Naval Postgraduate School Technical Report, NPS-MA-95-006, August 1995.

OTHER

Braccio, P. and Semtner, A.J., "Global Ocean Animations from the Los Alamos POP Model, Emphasizing the Southern Hemisphere," videotape of scientific ocean animations produced at the Naval Postgraduate School, 35 minutes, 1995.

Guest, A., Garwood, R.W., Jr., and Harcourt, R., "Oceanic Planetary Boundary Layer (OPBL) Home Page," on the Internet at http://www.oc.nps.navy.mil/~bird/, 1995.

INITIAL DISTRIBUTION LIST

1.	Defense Technical Information Center 8725 John J. Kingman Rd., STE 0944 Ft. Belvoir, VA 22060-6218	2
2.	Dudley Knox Library, Code 52 Naval Postgraduate School Monterey, CA 93943-5100	2
3.	Research Office, Code 09 Naval Postgraduate School Monterey, CA 93943-5000	1
4.	Chairman, Code OC Department of Oceanography Naval Postgraduate School Monterey, CA 93943-5000	5
5.	Associate Chair for Research, Code OC Department of Oceanography Naval Postgraduate School Monterey, CA 93943	1
6.	Dean, Division of Operational and Applied Science Code 08 Naval Postgraduate School Monterey, CA 93943-5000	1